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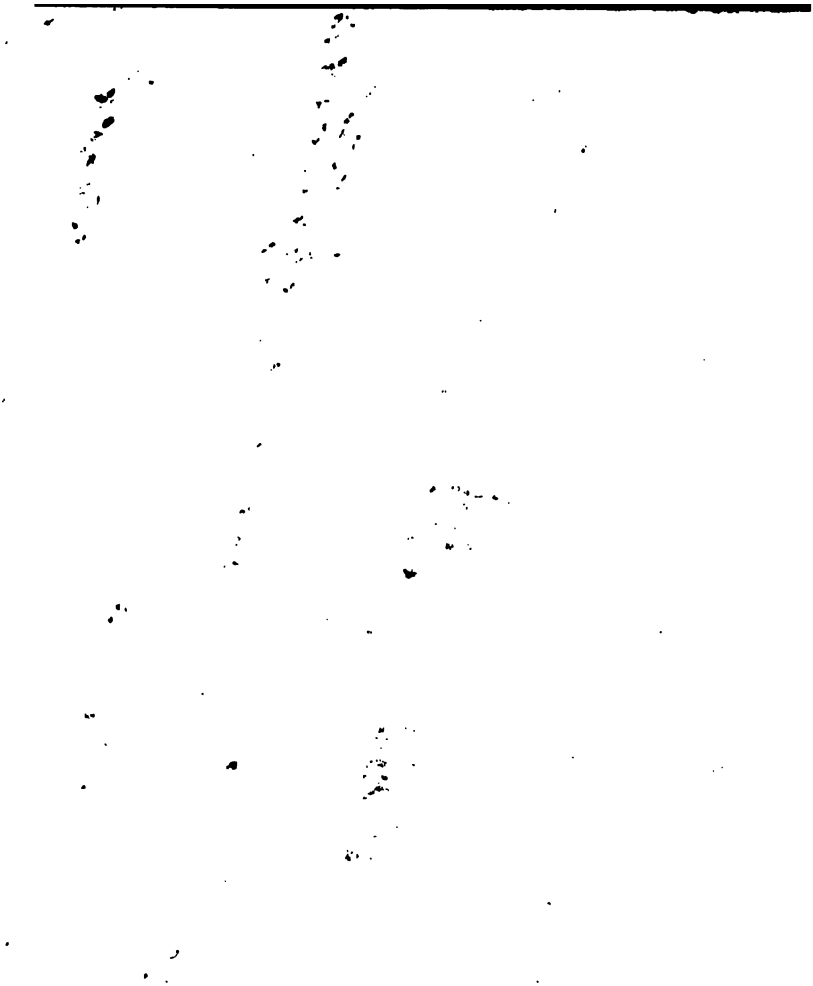


[*ENTERED AT STATIONERS' HALL.*]

TREATISE ON THE

ARRANGEMENT, APPLICATION, AND USE

OF

SLIDE RULES,

FOR PURPOSES OF

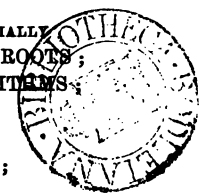
ENGINEERS', MECHANICS', AND OTHER CALCULATIONS,

WITH

DESCRIPTION OF IMPROVED INSTRUMENT
ADAPTED FOR QUESTIONS OF

INVOLUTION AND EVOLUTION, ESPECIALLY
SQUARE AND CUBE POWERS AND ROOTS;
COMMON AND HYPERBOLIC LOGARITHMS;
SINES, CO-SINES, &c., OF ANGLES;

AND NUMEROUS EXAMPLES;



BY

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PREFACE.

The present work deals with a subject which does not receive the attention it deserves, especially from artisans, and as the neglect is imagined to arise, mainly, in consequence of prevailing notions that "many and great difficulties have to be overcome in acquiring a knowledge of it; and the knowledge when acquired is of little practical use," the object of these pages is to show the fallacy of these notions, and to point out some of the advantages which even a partial acquaintance with it is calculated to ensure.

True, the subject is a very old one, has already received attention from numerous authors, and to many individuals another treatise respecting it will appear unnecessary; and yet, during a practical acquaintance with mechanical engineering for more than forty years, the present author has often felt the want of fuller and clearer information on the arrangement, application and use of slide rules for various calculations than he could obtain from the treatises at his command; and at the same time as he thankfully acknowledges his own indebtedness to the works of Farey, Routledge, Bevan, and others for the assistance they have afforded; and to Messrs. Aston and Mander, the noted scale and mathematical instrument makers, Soho, London, for the faithfulness with which they have carried out his design; he offers the following remarks and illustrations, and what he considers an improved instrument, to those still labouring under the inconvenience before alluded to, who he trusts will benefit by giving them careful perusal and consideration.

ERRATA.

Page 37.—10th line from bottom, for "0·335" read "0·0335."

Page 45.—7th line from bottom, for "triangle whose three points just meet" read "triangle one of whose three points, as M′, G′, is in."

ON THE SLIDE RULE.

Since the commencement of the present century innumerable inventions and improvements have been made, whereby operations that formerly had to be performed by manual labour are now done much better and far more readily by or with the aid of machinery; but there are still various branches of trade wherein sundry old-fashioned implements have occasionally to be used, in order to satisfactorily accomplish by hand, what machinery cannot conveniently always be applied to.

The mallet and chisel, saw and plane, hammer and drift, are among many familiar instances of implements required in the daily occupation of mason, carpenter, and smith; and the implements, or instruments for measuring with, common to most mechanical trades, are known in English workshop phraseology by the titles of "two foot," non-slide, and slide rules.

Non-slide rules, designed exclusively for measuring instruments, have figures and divisions representing inches and parts of an inch similarly marked on both faces; but slide rules have usually only one face so marked, the other being provided with a slide, several peculiarly divided lines, and with numerous figures and tables of numbers, termed constants or gauge points, which have been considered by their respective designers most appropriate for the particular purposes of calculations they were made to serve.

Any person thoroughly acquainted with the peculiarities of operatives in English mechanical engineering establishments, will have noticed the systematic way in which addition and subtraction of dimensions are often performed on non-

slide rules, and can testify to the facility and accuracy with which answers are obtained from selecting on the rule the largest of those dimensions, and counting the smallest to or from it, accordingly as the question of addition or subtraction.

For the sum and difference of say $6\frac{7}{8}$ and $3\frac{5}{8}$:—counting

One, two, three ins. five-eighths to $6\frac{7}{8}$ = sum $10\frac{1}{2}$
Do. - - do. - - do. - from $6\frac{7}{8}$ = difference $3\frac{1}{4}$; and

For the sum and difference of say $10\frac{1}{2}$ and $5\frac{3}{8}$:—counting

Five and three-eighths to $10\frac{1}{2}$ = sum $15\frac{7}{8}$
Do. - - do. - from $10\frac{1}{2}$ = difference $5\frac{1}{8}$

It will be obvious, however, from very little consideration, that applications similar to those in the preceding examples can be of no service in calculations often required by intelligent artisans; for although, so far as repetitions of equal numbers are concerned, similar results can be obtained

By Addition as by Multiplication, and
By Subtraction as by Division;

yet, in each instance, the former is a round-about, out-of-way mode for accomplishing what can readily be secured by the latter; therefore it is expedient to adopt the latter or some other system by which facility can be secured without materially affecting results. For, to give an example, useless waste of time would necessarily be involved by making ten separate additions or subtractions of say 69 to or from 780, when exactly similar results are obtainable by adding to or subtracting from 780 the product of ten times 69. But, in numerous complicated calculations, the system of figures by logarithms affords even greater facilities to computers than multiplication and division; and to Napier, its distinguished inventor, and Briggs, the improver of Napier's system, the scientific world is deeply indebted for the invaluable acquisition secured by the introduction of logarithmic numbers.

The following remarks and illustrations do not enter into details necessary for explaining the construction of Napier's or Briggs' Logarithms, neither are they given with an idea of informing or interesting individuals conversant with their use; but they are offered as a faint outline of the principle of logarithms applied in arranging slide rules to purposes of calculations, and to assist those who, although possessed of little or no knowledge of mathematics, yet are sufficiently acquainted with figures to readily understand and apply them.

Now, a number of figures arranged so that 0, the commencement of a unit increasing series in arithmetical progression, is placed in the first column opposite the starting figure (1) of any geometrical progression series in adjoining columns, as in

TABLE I.

Numbers in Arithmetical Progression.	Geometrical Progression Numbers, with sundry Ratios.			
	Ratio 2.	Ratio 3.	Ratio 4.	Ratio 10.
0	1	1	1	1
1	2	3	4	10
2	4	9	16	100
3	8	27	64	1,000
4	16	81	256	10,000
5	32	243	1,024	100,000
6	64	729	4,096	1,000,000
7	128	2,187	16,384	10,000,000
8	256	6,561	65,536	100,000,000
9	512	19,683	262,144	1,000,000,000
10	1,024	59,049	1,048,576	10,000,000,000

It will be seen on examination that the numbers in first column indicate the power or number of times the various

ratios require to be multiplied into unity and the succeeding products, to obtain the results over which they respectively stand: for instance,

1 in first col. is opp. the first power of Ratios 2, 3, 4, 10
2 - - do. - - do. - - second do. - - do. - - do.
3 - - do. - - do. - - third do. - - do. - - do.
4 - - do. - - do. - - fourth do. - - do. - - do.
5 - - do. - - do. - - fifth do. - - do. - - do.
and so on.

The figures in first column representing a series of indices or logarithms to the number opposite on the same line under the several ratios.

And logarithms being artificial numbers so contrived that

The sum of the Logs. of any two numbers } = { the Logarithm of the Product of those numbers.

The difference of Logs. of any two numbers } = { the Logarithm of the Quotient of those numbers.

The Log. of any number multiplied by the Index of any required power } = { the Logarithm of the required Power of that number.

The Log. of any number divided by the Index of any required Root } = { the Logarithm of the required Root of that number

Then, to apply Table I. to examples for simple multiplication and division of numbers for which it is adapted, the product or quotient of any two numbers under any one Ratio in Table, is equal to the number in same column that is represented by their logarithmic sum or difference.

Ex. 1.—From the column of numbers under Ratio 2 find the product of 16 times 32.

Opp. 32 under Ratio 2 is its Log. 5 in first column
Opp. 16 - - do. - - do. - Log. 4 - - do. - -
5 plus 4 = 9, and
9 in first column is opposite the answer 512 under Ratio 2.

Exs. 2 and 3.—From Ratios 2 and 4 in Table find the product of 16 times 64.

Opp. 16 under Ratio 2 is Log. 4 in first column
Opp. 64 - - do. - - Log. 6 - - do. - -
4 plus 6 = 10, and
10 in first column is the Log. of, and opposite to the answer 1024 under Ratio 2.

Or, Opp. 16 under Ratio 4 is Log. 2 in first column
Opp. 64 - - do. - - Log. 3 - - do. - -
2 plus 3 = 5, and
5 in first column is the Log. of answer 1024 under Ratio 4.

Ex. 4.—Required the product of 27 times 243.

Under Ratio 3 in Table is 243 opp. its Log. 5
- - Do. - - - do. - - 27 - do. Log. 3
5 plus 3 = 8, and
8 is the Log. of answer 6561 under Ratio 3.

Ex. 5.—What is the Quotient of 6561 divided by 27?

In the column under Ratio 3 is 6561 opp. its Log. 8
- - Do. - - - - do. - - - - 27 - - do. - - 3
8 less 3 = 5, and
5 in first column is the Logarithm of and opposite the answer 243 under Ratio 3.

Ex. 6.—From the column headed Ratio 4 find the Quotient of 16,384 divided by 64.

Opp. 16,384 under Ratio 4 is Log. 7 in first column
Opp. - - 64 - - - do. - - - Log. 3 - - do. - - -
7 less 3 = 4, and
4 in first column is opposite the answer 256 under Ratio 4.

Or, to apply the same Table to questions of Involution and Evolution.

The Product or Quotient of the logarithm of any number in Table (for which the table is adapted)

multiplied by the Index or Exponent of any required Power, or
divided - - - do. - - - do. - - - do. - - Root
gives the Logarithm of that Power or Root; and as

The Index or Exponent of second Power or Square is 2
- - Do. - - - do. - - third - - do. - - Cube - is 3
- - Do. - - - do. - - fourth - do. - - - - - - is 4
- - Do. - - - do. - - fifth - - do. - - - - - - is 5
&c., &c.

Then, to find the Square and Square Root of 16.

Exs. 1 and 2.—Opposite 16 under Ratio 2 is Log. 4 in first column; the Index of Square is 2;

Log. 4 × Index 2 = Log. 8 opp. answer 256 for Square, and
Log. 4 ÷ Index 2 = Log. 2 - - do. - - - 4 for Square Root.

Or, Exs. 3 and 4.—To find the Cube and Cube Root of 64 from the column headed Ratio 4.

Opp. 64 under Ratio 4 is Log. 3 in first column.
The Index for Cube or third Power is 3.

Log. 3 × Index 3 = Log. 9
Log. 3 ÷ - do. - = Log. 1: and

Log. 9 in first column is opp. the Cube 262,144 under Ratio 4.
Log. 1 - - - do. - - - do. - - - Cube Root 4 - - - do. - -

Exs. 5 and 6.—From the column headed Ratio 4 find the fifth Power of 4, and fifth Root of 1,048,576.

Opp. 4 under Ratio 4 is Log. 1 in first column
And the Index for fifth Power is 5, therefore

Log. 1 × Index 5 = Log. 5, which in first column is opp. 1,024 in fourth column;
Also 1,048,576 under Ratio 4 is opp. Log.10 in first column.
Log. 10 ÷ Index 5 = Log. 2; and
Log. 2 in first column is opp. 16 under Ratio 4 for the fifth Root of 1,048,576.

And thus, although Table 1 of unit increasing Logarithms, from its exceedingly limited scope, applies to comparatively few numbers, yet it and the accompanying examples serve to illustrate the same principle as adopted with the elaborate Logarithmic Tables made by Hutton and other eminent mathematicians, to facilitate the innumerable intricate calculations which have occasionally to be made.

But the system of Logarithms in most general use is that adopted by Briggs, wherein

0	represents	the	Logarithm	of	-	-	1
1	-	-	do.	-	-	do.	-	-	-	-	10
2	-	-	do.	-	-	do.	-	-	-		100
3	-	-	do.	-	-	do.	-	-	-		1,000
4	-	-	do.	-	-	do.	-	-			10,000
&c.	-	-	do.	-	-	do.	-	-	-		&c.

The tables of Hutton, &c., before mentioned, embrace Logarithms of numbers innumerable, and what are termed Hyperbolic Logarithms are in the proportion to common Logarithms as 2·3025851, or very nearly 2·3 to 1.

According to "Hutton's Tracts," published in 1812, "the first publication of Logarithms was made by Baron Napier, of Merchiston, Scotland, in 1614," and "on the publication of

Napier's Logarithms, Briggs, Professor of Geometry, Gresham College, London, immediately applied himself to the study and improvement of them."

In 1623 the celebrated Gunter applied the Logarithms of numbers to straight lines drawn on a rule in the form of a two-foot scale, called the Gunter, which was used for navigation and other purposes at the time Hutton wrote.

In 1627 Oughtred and Wingate dispensed with the compasses required for Gunter's scale, by drawing Logarithmic lines on two separate rules sliding against each other, and Oughtred applied the system to concentric circles in the same year; in 1650 the spiral form of lines was introduced; in 1657 Partridge made the arrangements which continued in use until 1812, and since 1812 various Slide Rules have been recommended, all based upon the same principle; the variations consisting merely of different combinations of lines, or adaptation of constant numbers, or guage points, to meet the particular purpose their respective designers wished to provide for.

Farey, in his "Treatise on the Steam Engine," published in 1827, says "that lines upon sliding rules have been combined in various ways to suit the purposes of particular calculations, but that which has been found most convenient for the use of engineers was arranged by Mr. Southern, under the direction of Mr. Watt, expressly for the use of the engineers of Messrs. Boulton and Watt's manufactory at Soho, and is in consequence called the Soho rule:" and again, "the habit of using sliding rules for computations upon all occasions is almost confined to those who have been educated at Soho," although, since Farey wrote, the Slide Rule has been applied to calculations in other establishments than Boulton and Watt's, and the various arrangements of Bevan, Routledge, Carrett, Hawthorne, Hoare, &c., used.

From the description given in Farey's treatise, the lines, figures, and divisions on A,B,C,D of the Soho and Routledge instruments are evidently alike, therefore any remarks which

apply to one equally apply to the other and all similarly marked instruments; and as the arrangement now proposed and hereafter described has its lines A,B,C,D similarly marked to the Soho and Routledge, so the operations (concerning those lines only) will be alike for all three; while the lines on the proposed instrument, extra to A,B,C,D, have a special application to purposes of calculations hereafter explained, for which the other two instruments are not adapted.

To describe the proposed arrangement.

The improved instrument consists of a frame and slides of boxwood or other material suitable for receiving clear, distinct impressions of lines, figures and divisions; each face of the breadth of frame being divided into five spaces, or strips of lines extending the whole length necessary for containing the various divisions, and each space or strip having a distinguishing letter or name on one or both ends to afford convenient reference.

Commencing with face of instrument marked No. 1 on its right hand corner, and taking the respective spaces or strips in the order they are placed:—

1st Space, marked CUBE $R^{T.}$, is occupied with a set of single radius lines, figures and divisions, representing the logarithmic scale measurements of cube roots of numbers expressed by the figures and divisions on the continuous lines of second space marked N.

The 2nd Space, N (or slide), contains three radii of logarithmic divisions whose united lengths make up that of the single radius on 1st space, and the figures and divisions on N represent numbers whose cube roots are expressed by the figures and divisions on the 1st space.

3rd and 4th Spaces marked A, $\frac{B}{C}$, are similar to N.

5th Space, marked D, contains one radius and a-half of logarithmic measurements; one radius of which is equal to two on contiguous line C; and the one and a-half conjointly on D equal to the three on C.

And, although the first of the five spaces alluded to contains only one radius; while each of the second, third, and fourth, contains three repetitions of a radius; and the fifth space contains one radius and a-half; and in consequence the figures and divisions on line marked Cube Root are necessarily wider apart than those on line D; and those on line D than those on the respective lines N,A,B,C; yet a

SCALE

of 1000 equal parts = 1 Radius;

whether the radius be long or short, serves to set out the proper positions for the respective figures and divisions to express the numbers on that radius whose logarithmic distances from the starting point are represented by the three nearest decimals of Briggerian Logarithms given in authentic tables.

Thus, on any radius of logarithmic measurements set out from suitably prepared scales,

1	is	opp.	its	Log.	measure	0·0	=	0	parts	from	scale
2	-	-	-	do.	-	-	-	0·301	=	301	-	-	do.	-
3	-	-	-	do.	-	-	-	0·477	=	477	-	-	do.	-
4	-	-	-	do.	-	-	-	0·602	=	602	-	-	do.	-
5	-	-	-	do.	-	-	-	0·699	=	699	-	-	do.	-
6	-	-	-	do.	-	-	-	0·778	=	778	-	-	do.	-
7	-	-	-	do.	-	-	-	0·845	=	845	-	-	do.	-
8	-	-	-	do.	-	-	-	0·903	=	903	-	-	do.	-
9	-	-	-	do.	-	-	-	0·954	=	954	-	-	do.	-
10	-	-	-	do.	-	-	-	1·	=	1000	-	-	do.	-

And as one radius of the lines on fifth space = twice
and one - do. - do. - first space = thrice
the length of each radius of the lines C and N, to which they are contiguous; and

2 is the Index or Exponent of second Power or Square,
3 - - do. - - do. - - third Power or Cube.

Then, on the principle of Logarithms, the

Figures, &c., on C represent Squares of those on D.
- - Do. - - D - do. - Sq. Roots - do. - C.
- - Do. - - N - do. - Cubes - - do. 1st sp.
- - Do. - - 1st space - Cube Roots do. - N.

And two lines can be arranged in similar manner for any other power and root, by making the length of one radius in the same proportion to the other as the index of the required power is to unity, and setting out both logarithmically as before explained.

No. 2 FACE,

Or the opposite side of instrument to that just described, contains five spaces, as follow:—

The 1st Space, marked COM. LOG$^{S.}$, being occupied with figures and divisions representing the common or Briggerian Logarithms of Numbers indicated by the figures and divisions on the second Space marked Numbers.

The 2nd Space, or Slide marked NUMBERS, corresponds to the length occupied by the contiguous space on each side; and to obtain conspicuous divisions throughout the length, they are set out like the CUBE R$^{T.}$ line of Face No. 1; with

The figures and divisions on

upper edge, opposite their COM. LOG$^{S.}$ on 1st space; and on
lower do. - - do. - HYP. LOG$^{S.}$ on 3rd space.

3rd Space, marked HYP. LOGS., is occupied with figures and divisions placed at distances from mark at 0 in proportion to those on the line COM. LOGS. very nearly as 1 is to 2·3; the hyperbolic logarithms of similar numbers being equal to common logarithms multiplied by 2·3025851.

4th Space, marked $\frac{\text{CO. SINES}}{\text{SINES}}$, contains two sets of figures and divisions representing degrees and half degrees in the quadrant of a circle whose radius is 1; advancing

on line CO. SINES, from right hand to left
on line - SINES, - - - left - do. - right,

and so arranged that their equivalents are represented by the figures and divisions opposite on the fifth space.

And lastly, to make more distinguishable the marks representing the equivalents of the degrees towards the right hand end of the

5th Space, marked NUMBERS. The figures and marks, occupying a length on this space equal to radius 90° on lines $\frac{\text{CO. SINES}}{\text{SINES}}$, are arbitrarily placed wider asunder as the divisions advance from the left hand to the right; or, in other words, the widest divisions, or those at the right hand, represent the least differences of equivalents for the degrees which are marked on the fourth space to agree with authentic tables.

Now, from the preceding description of proposed Instrument, it will be evident from very little consideration, that the contiguous lines on both faces will have to be used more or less in conjunction, accordingly as they are adapted for the calculations which require to be made. Thus, on

No. 1 FACE

Cu. Rt. line, with line N, for questions of Cu. Rts. and Cubes
The N - do. - A, - do. - Multn. and Division
- A - do. - B, - do. - - - do. - -
- C - do. - D, - do. - Squares and Sq. Rts.

On

No. 2 FACE

Com. Logs. with NUMBERS, for questions of Com. Logs.
Hyp. Logs. - do. - do. - do. - Hyp. Logs.
Cosines - do. - do. - do. - Cosines of Angles
Sines - do. - do. - do. - Sines of Angles

And as the result of any operation can be left undisturbed on the set of lines where obtained, without hindering, but rather helping, the operation which has immediately to follow on another; so, the adoption of several sets of lines on one instrument is better adapted for calculations than when only one set is available.

Having shown the principle on which Slide Rules are generally arranged for facilitating computations, and the arrangement of instrument proposed, the reader's attention is next directed to

NOTATION

or the method of counting or estimating the figures and divisions on the various lines; and as on a thorough mastery of this important branch of the subject a sound practical knowledge of the application and use of Slide Rules depends, the five following propositions are submitted for notice.

Prop. 1st.—The figures on any one of the several lines N,A,B,C of No. 1 face of proposed instrument, may represent whole numbers, or decimals; providing properly proportioned values are assigned to the remaining figures and divisions on the same line. Thus, figure 1 on the left hand or commencement of each of the lines N,A,B,C, may

represent ·1, or 1, or 10, or 100, or 1000, &c., when
2 will represent ·2, - 2, - 20, - 200, - 2000, &c.
3 - do. - ·3, - 3, - 30, - 300, - 3000, &c.
and so on.

Or, supposing the figures on same lines on

1st radius represent 1; - 2; - 3; - 4 &c., those on
2nd - - do. - - 10; - 20; - 30; - 40 &c., - do. -
3rd - - do. - - 100; - 200; - 300; - 400 &c.,

and, the divisions between the figures on each radius, will have values in proportion to those figures and to the number of divisions between them.

Prop. 2nd.—The figures and divisions on any of the lines N,A,B,C, may or may not have equal values to similar figs., &c., on any contiguous line of the same set, providing the proportionate values assigned at the commencement of a calculation are maintained until that calculation is completed. Thus, the first 1 on the left hand of line N may be called decimal 1, or 1 unit, or 1 ten, or 1 hundred, or 1 thousand, or 1 ten thousand, &c.; while the first 1 on A may be 1 hundred, or 1 thousand, &c.; and the first 1 on B may at the same time represent unit, ten, hundred, or thousand, &c., providing the relative proportions started with on the various lines be maintained throughout the calculation for which the proportions are assigned.

Prop. 3rd.—The values of the various divisions on the several lines of accurately marked Slide Rules depend conjointly upon the values assigned to the figures, and on the number of divisions between the figures. Thus, taking the figures 3, 4, 5, on any radius of the several lines N,A,B,C, with twenty divisions between 3 and 4, and twenty between 4 and 5.

If 3 represents 30; 4=40; 5=50=difference 10, for 20 divisions each division = ·5

If 3 represents 300; 4=400; 5=500=difference 100, for 20 do. each division = 5·

If 3 represents 3000; 4=4000; 5=5000=difference 1000, for do. each division = 50

Or greater the value assigned to the figures, greater also is that represented by each of the divisions between the figures; and as in numberless calculations by Slide Rules, small divisions may represent large amounts, so, in such instances, correct answers will not only depend upon the instrument being accurately marked, but also upon the accuracy with which fractions of divisions are estimated when the answers fall between or wide of the marks. To illustrate this proposition more clearly—suppose 9, on any radius of any of the lines N,A,B,C, to represent 90,000, the 1 following on same radius will then represent 100,000; and as the space between 9 and 1 is only about $\frac{1}{4}$ in. for ten divisions, that short space, for the example supposed, represents 10,000, or each of its ten divisions 1,000; and whatever one half of one of these minute divisions may at any time represent, is equal to $\frac{1}{2}$ per cent. or 1 in 200, which is the greatest amount of error in calculations that needs be made with a moderately careful using of an accurate instrument.

Prop. 4th.—When numbers to be dealt with on Slide Rules contain more than three figures, exclusive of ciphers on the extreme right or left hand, approximate estimates of those number can not be depended upon as being nearer than within $\frac{1}{2}$ per cent. of accurate; and practically those divisions on the instruments are taken which most nearly represent the given number.

Thus, for 90765
9076·5
907·65
90·765
9·0765
·90765

the divisions on the instrument representing 908 would be taken for all the examples, because 90800 is nearer than 90700 to 90765; while the number of figures in answer would be resolved as hereafter shown.

Prop. 5th.—All calculations in figures being made of the four elementary operations of Arithmetic, Addition, Subtraction, Multiplication and Division, but principally the two last; and intricate calculations involving lengthy multiplications and divisions being more easily solved by Logarithms, or the principle adopted on Slide Rules, than by the common methods of arithmetic; the inference is, that accurate well arranged Slide Rules must be admirably adapted for assisting engineers and mechanics in numerous calculations, inasmuch as they afford ready means of obtaining results mechanically or by measurements, and of checking the tedious operations which have often to be made under the ordinary system.

Presuming the preceding propositions and remarks are clearly understood by the reader, his attention is next directed to the practical application and use of the several lines, figures and divisions on the proposed instrument; and firstly to those for solving questions in multiplication and division by the lines N,A,B.

Now, the figures and divisions on lines A,B of ordinary Routledge and Soho, and on N,A,B of improved instrument being alike, it matters not, so far as questions of simple multiplication and division are only concerned, whether the line A be used for

multiplicands and dividends
or multipliers and divisors;

but, in many instances, especially with the improved instrument, it is most convenient to appropriate the slides

N, and $\frac{B}{C}$, for multipliers and divisors,
and A for multiplicands and dividends,

and with the exceptions of instances where one setting of slide $\frac{B}{C}$ is used in conjunction with divisors on A conjointly with multipliers on D, this plan is adopted on the following pages.

Ex. 1.—Required the product of 7 times 9 by Slide Rule.

Here, according to previous instructions, the

Multiplicand 9 is to be read on line A
Multiplier 7 is to be read on line N or B,

and because the distance from

1 to 9 on A - - is Log. scale measurement of 9
and 1 to 7 on N or B is - do. - do. - of 7
both together is - do. - do. - of 63 Ans.

In other words, the Logarithm of 9 on A added to the Log. of 7 on N or B gives the same result, by addition, as obtained by multiplication in the ordinary way.

Exs. 2 and 3.—Required the products of 16 and 18 multiplied by 11.

From 1 to 16 on A is the Log. measurement of 16
- - 1 to 18 on A - - do. - do. - - 18
- - 1 to 11 on N or B do. - do. - - 11
16 on A + 11 on N or B = 176 on A for 1st answer,
and 18 on A + 11 on N or B = 198 on A for 2nd answer.

Or, 1 set on the multiplier line N or B
opposite the multiplicand on A,
opposite the multiplier on N or B
will be the answer on A.

And, in any multiplication of whole numbers, by reading the

Multiplicands on 1st radius of line A, and
Multipliers on - - do. - - N or B

the answer on 1st radius will contain one figure less than,
and on 2nd - - do. - - an equal number to,
the Multiplicand and Multiplier together;

while, if necessary, the units figure of answer can be obtained, mentally, by multiplying the figure in units place of multiplicand by that of the multiplier.

Thus, to find the Product of 14 times 23; 23 times 87; and 42 times 96—

23×14=23 on A + 14 on N or B=Ans. 322 on 1st rad. of A in three figures.
87×23=87 on A + 23 on N or B=Ans. 2001 on 2nd rad. of A in four figures.
96×42=96 on A + 42 on N or B=Ans. 4032 on 2nd rad. of A in four figures.

The Unit 2, in Ans. to 1st Ex., being from 4 times 3 = 12
- - 1, - do. - 2nd - do. - 3 times 7 = 21
- - 2, - do. - 3rd - do. - twice 6 = 12

EXAMPLES.

Required the Products of 70 times 112; 113 times 153; and 252 times 468.

Ex. 1.—112 × 70 = 112 on A + 70 on N or B;
Or 1 on N or B set to 112 on A
opp. 70 on N or B is 7840 on 1st rad. of A = Ans. in four figures.

Ex. 2.—153 × 113 = 153 on A + 113 on N or B;
Or 1 on N or B set to 153 on A
opp. 113 on N or B is 17,300 on A very nearly, in five figures on 1st radius.

Ex. 3.—468 × 252 = 468 on A + 252 on N or B;
or 1 on N or B set to 468 on A
opp. 252 on N or B is 118,000 on A very nearly, on 2nd radius in six figures.

And for the product of mixed whole numbers and decimals, or decimals only, the number of decimals in full answers is counted as in common decimal arithmetic, similar to the four following examples.

16· × 1·1 = 16 on A + 1·1 on N or B gives the Ans 17·6
on 1st radius of A;
1·6 × 1·1 = 1·6 on A + 1·1 on N or B gives the Ans. 1·76
on 1st radius of A;
·16 × 1·1 = ·16 on A + 1·1 on N or B gives the Ans. ·176
on 1st radius of A;
·16 × ·11 = ·16 on A + ·11 on N or B gives the Ans. ·0176
on 1st radius of A.

DIVISION.

For division of whole numbers, read the dividends and divisors on the second radius of lines A, and N or B, and the answers on same radius will contain one figure more than, and on the first radius on equal number of figures to, the difference between the number of figures in the dividends and divisors; while the value of the answers will be obtained by the method directly opposite to that for multiplication; as follows:—

Dividends on A − Divisors on N or B = Answers on A;

or Divisors on N or B set to Dividends on A
opp. Unity on N or B are Answers on A.

Thus in Ex. 1.—For the Quotient of

176 divided by 11.

176 on A − 11 on N or B = Answer 16 on same radius of A
in two figures;

or 11 on N or B set to 176 on A
opp. 1 on N or B is 16 on A as before.

Ex. 2.—Required the Quotient of 784 divided by 112.

784 on A − 112 on N or B;
or 112 on N or B set to 784 on A
opp. 1 on N or B is Answer 7 on A in same radius, in one

figure, because the three figures in dividend less the three in divisor = 0, and answers on second radius are to contain one figure more than the difference.

Ex. 3.—To find the Quotient of 197,856 divided by 183.

Say 198,000 on A — 183 on N or B,
Or 183 on N or B set to 198,000 on A

opp. 1 on N or B is 1,080 very nearly, on the same radius of A, in four figures.

Ex. 4.—For the Quotient of 183,000 divided by 198.

183,000 on A — 198 on N or B,
Or 198 on N or B set to 183,000 on A

opp. 1 on N or B is 925 very nearly on A in three figures (so far as whole numbers are concerned); because the answer in this case is on first radius, and the number of figures must be equal to the difference between the six figures in dividend and the three in divisor.

Or another method of determining the number of figures in quotients, whole numbers, consists in so altering the dividends and divisors by reducing both decimally, or by hundreds, &c., that their relative proportions can be maintained and the divisors confined (mentally) to units of whole numbers.

Ex. 1st. $322 \div 14 = 32{\cdot}2 \div 1{\cdot}4$;
Or 32·2 on A — 1·4 on N or B = Ans. 23 on A.

Ex. 2nd. $2040 \div 24 = 204 \div 2{\cdot}4$;
Or 204 on A — 2·4 on N or B = Ans. 85 on A.

Ex. 3rd. $2040 \div {\cdot}24 = 20400 \div 2{\cdot}4$;
Or 20400 on A — 2·4 on N or B = Ans. 8500 on A.

Ex. 4th. $204 \div {\cdot}024 = 20400 \div 2{\cdot}4$;
Or 20400 on A — 2·4 on N or B = Ans. 8500 on A.

Ex. 5th. $20{\cdot}4 \div {\cdot}024 = 2040 \div 2{\cdot}4$;
Or 2040 on A — 2.4 on N or B = Ans. 850 on A.

And having thus given several examples on the lines N,A,B, of operations for multiplication and division separately, it is important to notice that the same lines can be used for a single operation of each conjointly, with one setting of Slide N or $\frac{B}{C}$, providing the operation for division be made first.

For, as the quotient of any two numbers in division represents the amount of dividend unity of the division is equal to, and the product of that quotient by any multiplier is obtainable by simple multiplication.

And from addition and subtraction of logarithmic measurements on Slide Rules similar results are obtainable to those by the ordinary modes of multiplication and division.

Then, by substitution,

(Dividends − Divisors) + Multipliers on Slide Rules give the same results as

Dividends ÷ Divisors × Multipliers by the ordinary mode.

Or from formula to suit the lines N,A, or B,A;

(Dividend on A − Divisor on N or B) + Multiplier on N or B = Answer on A; the simple minus and plus signs give instructions as to the particular operations which have literally to be performed in the solution of questions requiring only one operation each in multiplication and division.

EXAMPLES.

Ex. 1.—Multiply 12 by 9 and divide the product by 3, or what amounts to the same.

Divide 12 by 3, and multiply the quotient by 9
Or Do. 9 by 3, - do. - do. - by 12

Here (12 on A − 3 on N or B) + 9 on N or B,
or (9 on A − 3 on N or B) + 12 on N or B

gives the answer 36 on A from one setting of slide N or B

by making division first; whereas, two settings would be necessary should precedence be given to the operation for multiplication.

Ex. 2.—By the lines N,A, divide 84 by 12 and multiply the quotient by 9 :—

(84 on A − 12 on N) + 9 on N,
Or 12 on N set to 84 on A,
opp. 9 on N is 63 Ans. on A.

Ex. 3.—By the lines B,A, divide 960 by 16 and multiply the quotient by 36 :—

(960 on A − 16 on B) + 36 on B,
Or 16 on B set to 960 on A,
opp. 36 on B is 2160 Ans. on A.

Now all questions of Simple Proportion, or

SINGLE RULE OF THREE,

being worked out with one operation each of multiplication and division (like the examples just given); and proportion, direct or inverse, being resolvable into a common statement wherein the 3rd term being of the same kind as the answer, the 2nd term is less or greater than the 1st accordingly as the answer is to be less, or greater, than the 3rd term.

So, from a statement thus made, the

(quotient of 2nd term divided by 1st) multiplied by 3rd
or, (- do. - 3rd - - do. - -) - do. - 2nd

$$\text{The } \left.\begin{array}{l}(\text{2nd term on A} - \text{1st term on N or B}) \\ \quad + \text{3rd term on N or B - - - -}\end{array}\right\} = \text{Ans. on A}$$

$$\text{or, } \left.\begin{array}{l}(\text{3rd term on A} - \text{1st term on N or B}) \\ \quad + \text{2nd term on N or B - - - -}\end{array}\right\} = \text{Ans. on A}$$

from one setting of N or $\frac{B}{C}$, without inverting the slide, whether the question is one of Simple Proportion, direct or inverse.

EXAMPLES IN SIMPLE PROPORTION.

Ex. 1.—Required the value of 72 pounds of material reckoned at the rate of 18 pounds for 12 shillings.

In this question more requires more, or 72 pounds of material will necessarily have greater value than 18, and as the answer is required in money, and the third term in the statement has to be the same kind or denomination as the answer, and the second term greater than the first because the answer will be greater than the third.

As 18 : 72 :: 12 : Answer

is the statement for the question.

And (72 on A − 18 on N or B) + 12 on N or B,
or (12 on A − 18 on N or B) + 72 on N or B,

Or 18 on N or B set to 72 on A, opp. 12 on N or B,
or 18 on N or B set to 12 on A, opp. 72 on N or B is
the answer on A = 48 shillings.

Ex. 2.—If 18 men complete a piece of work in 12 days, how many equally effective men will be required to complete a similar piece in 72 days?

In this question more requires less, or a longer time will require fewer men, and therefore it is one of inverse proportion; and as the answer is required in number of men,

The statement is, As 72 : 12 :: 18 : Answer

or (12 on A − 72 on N or B) + 18 on N or B,
or (18 on A − 72 on N or B) + 12 on N or B,

or 72 on N or B set to 12 on A opp. 18 on N or B,
or 72 on N or B set to 18 on A opp. 12 on N or B
is the answer 3 days on A;

Or to find the fourth proportional of any three whole members,

The 1st term on N or B set to the 2nd term on A;
opp. 3rd - do. - is the 4th term on A

Or to find any two of the component parts of any given weight of material, in the same proportion as assigned for any other weight of the same; set the assigned components on N and B to assigned weight on A, and the answers on N and B will be opp. the given weight on A.

Ex.—On page 55 of the "Appendix to Third Report on the Coals suited to the Steam Navy," by Sir Henry de la Beche, C.B., F.R.S., and Dr. Lyon Playfair, F.R.S., the mean composition of average samples of Coals from West Hartley Main, Newcastle, is given—Carbon 81·85; Hydrogen 5·29; Nitrogen 1·69; Sulphur 1·13; Oxygen 7·53; and Ash 2·51 per cent.

Required by Slide Rule the approximate weight

of Carbon, Hydrogen,
Sulphur, and Ash,

in 1 ton or 2240 pounds of the same quality of Coal.

1st.—81·9 (for Carbon) on N, and 5·3 (for Hydrogen) on B, set to 100 pounds of Coal on A.

Opposite 2240 pounds of Coal on A is nearly 1835 pounds of Carbon on N, and 119 pounds Hydrogen on B.

2nd.—1·13 (for Sulphur) on N, and 2·51 (for Ash) on B, set to 100 pounds of Coal on A

opp. 2240 on A is 25·3 pounds of Sulphur on N,
- - do. - - 56·2 pounds of Ash - do.; or the

Answer in pounds=Carbon 1835; Hydrogen 119; Sulphur 25·3; Ash 56·2.

For Questions in

COMPOUND PROPORTION

Or Double Rule of Three, five terms being given to find the sixth; and the statement or proportion set out on two lines.

On 1st line—The 3rd term being of the same denomination as the answer; and the 1st term greater or less than the 2nd accordingly as the result on that line is to be less or greater than the 3rd,

On 2nd line,—The result from first line is the 3rd term, and the 1st term greater, or less, than the 2nd, accordingly as the 1st result is greater or less than answer.

Ex.—If 20 men mow 270 acres of grass in 18 days, how many men will be required to mow 330 acres in 24 days, at the same rate?

Taking time first; fewer men will be required to mow any piece of grass in 24 than in 18 days, and therefore the statement on 1st line will be

As 24 : 18 :: 20 : 1st result,

or the second term must be less than the first because the 1st result will be less than the 3rd term.

2ndly.—As more men will be required to mow 330 than 270 acres in the same time, the statement on 2nd line will be

As 270 : 330 :: 1st result : Answer,

or the 2nd term will be greater than the first because the answer will be greater than the 1st result.

Or, { 1st line, As 24 : 18 :: 20 : 1st result,
{ 2nd line, As 270 : 330 :: 1st result : Ans.

And working out the result on each line separately by Slide Rule,

1st (18 on A − 24 on N) + 20 on N = 15 on A
2nd (15 or 1st result on A − 270 on B) + 330 on B
= Answer on A very nearly 18·3.

INVOLUTION AND EVOLUTION.

To find by the improved Slide Rule, Powers and Roots, at least,

Squares and Square Roots,
and Cubes and Cube Roots,

as before remarked,

the operations have to be made on line C for Squares, in conjunction with line D for Square Roots; and

on line N for Cubes, in conjunction with line CUBE RT. for Cube Roots.

The answers for Squares containing on the

1st and 3rd radius of C one figure less than twice;
on 2nd radius of C exactly twice; and

The answers for Cubes containing

on 1st radius of N two figures less than thrice;
- 2nd - do. - N one figure less than thrice; and
- 3rd - do. - N exactly thrice as many figures as the number to be squared, or cubed.

Thus, in the following examples for

SQUARES,

1 on the left hand of D being opp. 1 on the left hand of C, then for

3^2; 3 on D = 9 on 1st and 3rd rad. of C = one figure
7^2; 7 do. = 49 on 2nd rad. - - of C = two figures
12^2; 12 do. = 144 on 1st and 3rd rad. of C = three do.
32^2; 32 do. = 1024 on 2nd rad. - - of C = four do.

Or, for questions of mixed whole numbers and decimals; or only decimals, the number of decimals in full answers is equal to twice the number of decimals to be squared.

Exs.—Required the squares of 3·5 and ·35 :—

3·5 on D is opp. 12·25 on 2nd radius of C or A
= 2 integers, and 2 decimals;
·35 on D is opp. ·1225 on 2nd radius of C, or A
= 4 decimals; and so on.

To apply the CUBE R$\overset{T.}{..}$, N, and A lines in finding the Cubes of any given numbers :—

Figure 1 on the left hand of N being opposite 1 on left of CUBE R$\overset{T.}{..}$ line; for the

Exs.—2^3, 3^3, 5^3, 11^3, 22^3, $2{\cdot}2^3$, $\cdot22^3$;

2	on	Cu.	Rt.	line	is	opp.	8	- -	on	1st	rad. of N and A=1 fig.
3	-	do.	-	do.		27	- -	- 2nd	-	do.	- =2 do.
5	-	do.	-	do.		125	- -	- 3rd	-	do.	- =3 do.
11	-	do.	-	do.		1331	- -	- 1st	-	do.	- =4 do.
22	-	do.	-	do.		10648	- -	- 2nd	-	do.	- =5 do.
2·2		do.	-	do.	-	10·648	-	- 2nd	-	do.	- =5 do.
·22		do.	-	do.	-	·010648	-	2nd	-	do.	- =6 do.

The same remarks applying to full answers of Cubes of mixed whole numbers and decimals, or exclusively decimals, as to squares; with the exception that for

Cubes, the answers contain three times; whereas for
Squares - - do. - - twice

the number of decimals cubed, or squared, as shown in the full answers; although in each of the last four examples the figures would be taken on instrument about 1330; 10650; 10·65; or ·01065, respectively.

Again, to find the Product of any number multiplied by the square, or cube, of any number.

When the first 1 on left hand of N and $\frac{B}{C}$ lines is
opp. - do. - - do. - CU. R$\overset{T.}{..}$ and A lines
any number on D is opposite its square on C,B, and A lines; any number on CU. R$\overset{T.}{..}$ line is opp. its cube on N, and A lines.

That is Squares, or Cubes, on A + Multipliers on B, and N, will give the respective answers accordingly as squares or cubes have to be dealt with; and questions of squares or cubes divided by any number, have the operations just reverse to those for multiplication.

Ex.—Required the Product of 7^2 multiplied by 40

7 on D line is opp. its square 49 on C, B and A

and

49 on A + 40 on N or B = 1960 Answer on A.

Ex.—Required the Quotients of 80 divided by 4^2
and the Quotients of 12^2 divided by 8

4 on D is opp. its square 16 on C,B,A,
12 on - - do. - - 144 on C,B,A.

80 on A−16 on B=Answer 5 on A for 1st example
144 on A−8 on B=Answer 18 on A for 2nd example

Ex.—Required the Product of 3^3 multiplied by 80
and the Product of 7^3 multiplied by 40

3 on Cube Root line is opp. its cube 27 on N, and A
7 on - - do. - - do. - - 343 on N, and A

and

27 on A+80 on N or B= 2160 on A for 1st Answer
343 on A+40 on N or B=13720 on A for 2nd Answer

Or the 2nd Ans. would be read on the Rule rather in excess of 13700.

Ex.—Required the Quotients of 400 divided by 5^3
and the Quotients of 8^3 divided by 9

5 on Cube Root line is opp. its cube 125 on N, and A
8 on - - do. - - do. - - 512 on N, and A

400 on A−125 on N or B=1st Ans. 3·2 on A,
and 512 on A− 9 on N or B=2nd Ans. on A very nearly 57

To find the

SQUARE ROOT OR CUBE ROOT

of any given number.

1st.—After writing down the given number, and placing a dot over the units place of integers, over every second figure from units place of integers for Square Root, and over every third figure from units place of integers for Cube Root; count the number of dots for the number of figures in answer.

2nd.—Find the Digit whose square, or cube, comes exactly (or nearest to, but less than, when not exactly) the number set off by the last dot to the left; and this digit will direct to whereabout on required root line the first figure of answer is, and on which radius of contiguous line the given number is to be read.

EXAMPLES.

Required the Square Root of $\dot{9}$, $1\dot{6}$, $1\dot{6}\dot{9}$ and $\dot{0}{\cdot}0\dot{1}\dot{6}\dot{9}$.

1.— 9 - on C= 3 on D=one figure, because one dot
2.— 16 - on C= 4 on D=one figure, because one dot
3.—169 - on C=13 on D=two figures, because two dots
4.— 0·0169 on C=·13 on D=two figures, because two dots

The first three answers consisting of whole numbers, and the last of two decimals. For questions entirely of decimals, only the dots over the decimals being counted.

Exs.—Required the Cube Rt. of $\dot{8}$, $6\dot{4}$, $5\dot{1}\dot{2}$, $\dot{8}0\dot{0}0$ and $6\dot{4}0\dot{0}0$.

1.— 8 on N= 2 on Cu. Rt. line in one fig., because one dot
2.— 64 do. = 4 - do. - do. - do. - -
3.— 512 do. = 8 - do. - do. - do. - -
4.— 8000 do. =20 - do. - two figs., because two dots
5.—64000 do. =40 - do. - do. - do. - -

Exs.—Required the Cube Root of $\dot{1}5\cdot62\dot{5}$ and $\dot{0}\cdot12\dot{5}$.

1st.—Opp. 15·625 on N, is 2·5 Ans. on Cube Root line in one integer and one decimal.

2nd.—Opp. ·125 on N, is ·5 Ans. on Cube Root line in one decimal, because in this example there are no whole numbers, and the number of figures in answer is equal to the number of dots over the decimals.

Or, to give in detail the operations for finding the approximate Cube Root of $6\dot{9},80\dot{0},00\dot{0}$

Firstly.—Dot every third figure of the given number counting from the first dot over the units place of integers, and there will be three dots to represent the number of integers in answer.

Secondly.—As the digit whose cube comes nearest to, but less than, the 69 set off by the last dot to the left is 4, so 4 points to the space between 4 and 5 on CUBE $R\dot{T}\cdot$ line as containing the answer (very nearly 412) opposite the given number 69,800,000 on the 2nd radius of line N.

Or again, any given weights, &c., of materials being in proportion to each other as the squares, or cubes, of the dimensions,

The given dimension on D set to its given weight on C, opposite any dimension on D is its weight on C; or,

The given dimensions on CUBE $R\dot{T}\cdot$ line set to its weight on N, opposite any dimensions on CUBE $R\dot{T}\cdot$ line is its weight on N, accordingly as they are in proportion to their squares, or cubes.

Exs.—Suppose the weight of any given length of 4 ins. square material is 6 pounds; required the weights of similar lengths of similar material, 5 and 9 inches square:—

Here, 4 (ins.) on D, or its sq. 16 on A, set opp. 6 (lbs.) on $\frac{B}{C}$;
- 5 - - do. - - 25 - is - 9·4 - do. -
- 9 - - do. - - 81 - is - 30·4 - do. -

And—Suppose a 4 inch cube = 20 pounds; then for the weight of 5 and 6 inch cubes of similar material:—

4 (ins.) on CU. R^{T} line=cube 64 on A, set to 20 (lbs.) on N
opp. 5 - - do. - - = - 125 on A, is - 39 - do. -
opp. 6 - - do. - - = - 216 on N, is - 67·5 do. -
for Answers.

And thus, the ordinary method of obtaining results by

Multiplication, Divison,
Squares, Square Roots,
Cubes and Cube Roots,

can, in great measure, be advantageously dispensed with for numerous calculations, by applying the lines on No. 1 Face of the Improved Slide Rule.

But, occasionally, calculations have to be made for powers and roots represented by indices more complex than for square, or cube; and which are comparatively easy and pleasant, or irksome and disagreeable, accordingly as Tables of Logarithms are, or are not, made use of; and, as on

FACE No. 2

the figures and divisions on Slide represent numbers for which the figures and divisions on COM. LOG^{S} line represent Common Logarithms to three places of figures; so with very little alteration "Hutton's Description and Use of Logarithmic Tables" apply to those lines.

Thus, the figures and divisions between the beginning and ending of radius of Common Logarithms on Face No. 2, representing decimals of that radius; the corresponding natural numbers represented on slide marked NUMBERS, may be either integers, or decimals, or mixed numbers (the same figures, whatever their denomination, having the same decimal logarithm), providing the proper index, or characteristic, or integer number, is prefixed to the decimal part

of the logarithm which expresses the distance, the highest denomination, or left hand figure of the natural number is from the units place; and the utility of the lines for obtaining approximate results of complex powers and roots is hereafter illustrated.

That is, if the natural number consists of only one place of integers or whole numbers, the index to its logarithm will be 0; if of two, three, four, five, &c., integers, the Index of their Logarithms will be respectively 1, 2, 3, 4, &c., or one less than the number of integer places; and the same figures, made negative, express in similar way the number of figures the extreme left hand digit (1, or upwards) of questions, exclusively decimals, is from the units place of integers.

Thus according to Hutton's Tables of Briggs' Logarithms:

Log. of	2·11	is 0·3242825, and Index of Log.	is 0
Do.	21·1	is 1·3242825, - - do. - -	is 1
Do.	211·	is 2·3242825, - - do. - -	is 2
Do.	2110·	is 3·3242825, - - do. - -	is 3
Do.	21100·	is 4·3242825, - - do. - -	is 4

For the same figures exclusively decimals:—

Log. of	·211	is $\bar{1}$·3242825, while the Index of Log.	is $\bar{1}$
Do.	·0212	is $\bar{2}$·3242825, - do. - - do. - -	is $\bar{2}$
Do.	·00211	is $\bar{3}$·3242825, - do. - - do. - -	is $\bar{3}$

The Index or characteristic figure of the Logarithm of the decimals being equal to the number of places of figures the left hand digit 2 of the decimals is from the unit place of integers; and such characteristics having a minus or negative sign placed over them.

But as the solution of questions, entirely decimals, may be considered to imply that more accurate results are required than within the occasional one-half per cent attainable on Slide Rules, the consideration and application of negative characteristics will not further be noticed on these pages.

To show the application of contiguous lines, COM. LOGS. and NUMBERS in finding Common Logarithms, when approximate results are sufficiently near for practical purposes.

EXAMPLES.

For the Common Logarithms of

1·08; 1·37; 1·52; 20·3; 24·7; 343; 389; 1010

1·	on line	NUMS.	being	set	opp.	0·	on	COM.	LOGS.			
1·08	- -	do.	-	will	be	opp.	·0335	-	do.	-		
1·37	- -	do.	-	-	do.	-	·137	-	do.	-		
1·52	- -	do.	-	-	do.	-	·182	-	do.	-		
20·3	- -	do.	-	-	do.	-	·308	-	do.	-		
24·7	- -	do.	-	-	do.	-	·393	-	do.	-		
343·	- -	do.	-	-	do.	-	·535	-	do.	-		
389·	- -	do.	-	-	do.	-	·590	-	do.	-		
1010·	- -	do.	-	-	do.	-	·0043	-	do.	-		

and as

each of the three first examples contains 1 integer
- do. - fourth and fifth - do. - 2 integers
- do. - sixth and seventh - do. - 3 do.
and the last example - - - do. - 4 do.

So by the instrument, the Common Logarithm of

1·08	is 0·335,	instead of	0·0334238	by	Tables	
1·37	is 0·137	- do. -	0·1367206	-	do.	-
1·52	is 0·182	- do. -	0·1818436	-	do.	-
20·3	is 1·308	- do. -	1·307496	-	do.	-
24·7	is 1·393	- do. -	1·392697	-	do.	-
343·	is 2·535	- do. -	2·5352941	-	do.	-
389·	is 2·590	- do. -	2·5899496	-	do.	-
1010·	is 3·0043	- do. -	3·0043214	-	do.	-

Or, the answers by the rule are considerably within one-half per cent. of the answers given in last column from

Hutton's Tables; the characteristics of the logarithms being represented by one figure less than there are places of whole numbers in the given examples.

Or, To find by the instrument the natural numbers corresponding to the Common Logarithms

0·643; 1·784; 2·865; and 3·746.

Look on COM. LOGS. line for the decimals only, of the given Logarithm, and opposite, on NUMBERS line, is the answer in one more place of integers than the characteristic of given Logarithm expresses.

That is, the decimal

·643 on COM. LOGS. line is nearly opp. 440 on NUMBERS
·784 - - do. - - - do. - - - 608 - do. -
·865 - - do. - - - do. - - - 733 - do. -
·746 - - do. - - - do. - - - 557 - do. -

and as the characteristic of Logarithm for 1st Example is 0; for 2nd Ex. is 1; for 3rd Ex. is 2; and 4th Ex. is 3; the whole numbers or integers in answers will contain one more figure than the respective characteristics express.

Or, the answer obtained by the rule for the Common Logarithm

0·643 is 4·4, instead of 4·3955 by Hutton's Tables
1·784 - 60·8 - do. - 60·814 - - do. - -
2·865 - 733· - do. - 732·83 - - - do. - -
3·746 5570· - do. - 5571·9 - - - do. - -

Having the

1 figure 4 for characteristic 0, in 1st ex.
2 figures 60 - - do. - - 1, in 2nd ex.
3 do. 733 - - do. - - 2, in 3rd ex.
4 do. 5570 - - do. - - 3, in 4th ex.

Or, To apply Tables of Logarithms in finding any power, of any number, be the power ever so complex.

The Common Logarithm of given number, multiplied by the index of required power, gives the Logarithm of Answer.

And the contrary operation gives the Log. of Root.

Or, by the instrument, using both faces of it—

1st. Opposite the given number on NUMBERS line is its Log. on COM. LOG$^{S.}_{..}$ line;

2nd. Common Log. of given number on A + index of required power on N or B = Log. of Product on A;

3rd. Opposite the last result on COM. LOG$^{S.}_{..}$ line is Answer on NUMBERS line;

And for Roots, the operations reversed.

To give practical illustrations of the complex powers occasionally required, and to afford some idea of the trouble involved in obtaining such, without, and with Tables of Logarithms.

The paper entitled "Experimental Researches on the Strength of Pillars of Cast Iron," read by Eaton Hodgkinson, Esq., F.R.S., &c., and published in the "Philosophical Transactions" for 1840, gives the strengths for different dimensions of pillars in proportion

Inversely—as the 1·7 power of their length in feet; and
Directly —as the 3·6 power very nearly of their diameters in inches, therefore as

Exs.—Find the 1·7 power of 9; or $9^{1.7}$
and the 3·6 power of 4; or $4^{3.6}$

Now, the 1·7 power of 9; or $9^{1.7}$; or $9^{1\frac{7}{10}}$; or $9^{\frac{17}{10}}$ is equal to the 17th power of the 10th root of 9.

Likewise, the 3·6 power of 4; or $4^{3·6}$; or $4^{\frac{36}{10}}$; or $4^{\frac{18}{5}}$ is equal to the 18th power of the 5th root of 4; and

In both cases a formidable array of figures is necessary should Tables of Logarithms not be made use of.

To use Tables of Logarithms; or, the lines on Instrument, Then,

1st.—By Hutton's Tables—Log. of 9 = 0·9542425
Index of 1·7 power = 1·7
0·9542425 × 1·7=Log. 1·62221225 of number very nearly 41·9

2nd.—By Hutton's Tables—Log. of 4 = 0·60206
Index of 3·6 power = 3·6
0·60206 × 3·6=Log. 2·167416 of number very nearly 147·3

Or by the Instrument,

9 on NUMBERS line is opp. Log. 0·954 on COM. LOGS. line
4 - do - - do. - - do. - 0·602 - - do. - -
0·954 on line A+1·7 (Index) on N=Log. 1·622 on A of 41·9 nearly
0 602 do. A+3·6 - do. - B=Log. 2·17 on A of 148 nearly

The answers being obtained on Instrument sufficiently accurate to meet innumerable practical purposes.

HYPERBOLIC LOGARITHMS.

The Hyperbolic Logarithms of numbers from 1 to 10 inclusive, are shown on the opposite side of line NUMBERS to COM. LOGS.

Natural numbers

1	on	NUMS.	line,	being	opp.	com. log.	0	and	hyp. log.	0
2	- -	do.	- - -	do.	- -	0·301	-	do.	-	0·693
3	- -	do.	- - -	do.	- -	0·477	-	do.	-	1·098
4	- -	do.	- - -	do.	- -	0·602	-	do.	-	1·386
10	- -	do.	- - -	do.	- -	1·	-	do.	-	2·303

and Hyperbolic Logarithms of numbers less than 1, and greater than 10, are obtainable very nearly from multiplying the Common Logarithms by 2·3 arithmetically, or by the Instrument

Common Log. on A + 2·3 on N or B = Hyp. Log. on A.

Thus, to find on the instrument, Hyp. Logs, of 6, 7, 9

Set 1 on NUMBERS line opposite 0 on Hyp. Logs. line, and
opp. 6 - - do. - - will be 1·792 nearly on do.
- 7 - - do. - - - do. - 1·946 - do. - -
- 9 - - do. - - - do. - 2·198 - do. - -

Or, to find the Hyperbolic Logarithms of 13, 73, 132, 643

Set 1 on NUM$^{S.}$ line opposite 0 on COM. LOG$^{S.}$ line, and
opp. 13 - - do. - will be 1·114 - - do. - do.
- 73 - - do. - - do. 1·863 - - do. - do.
- 132 - - do. - - do. 2·120 - - do. - do.
- 643 - - do. - - do. 2·808 - - do. - do.

and

1·114 on A + 2·3 on N or B = 2·56 on A for hyp. log. of 13 nearly
1·863 on A + do. do. = 4·29 do. - do. - 73 do.
2·12 on A + do. do. = 4·88 do. - do. - 132 do.
2·808 on A + do. do. = 6·47 do. - do. - 643 do.

And, lastly, the application and use of the contiguous lines marked

CO. SINES
SINES
NUMBERS

are easily attainable, providing the properties of circles, angles, and right-angled triangles be known.

From the usual

DEFINITIONS.

The diameter of a circle is a straight line passing through the centre to its periphery or circumference on two opposite sides, as AC; and the radius is equal to half its diameter, as AO, or OC.

Every circle, great or small, is supposed to have its circumference divided into 360 equal parts, called degrees; or the quadrant, or quarter circle, into 90 degrees; quadrants being represented by A O B, C O B, for circle ABCD.

An angle is the space intercepted by any two lines meeting in a point, as A'O, M'O and C'O, G'O meeting at O; and the number of degrees intercepted at the circumference between the two lines is the measure or quantity of the angle.

The measure of Angle A'OM' being 60° or 60 degrees
- Do. - do. - C'OG' do. 40° - 40 do.
- Do. - do. - CON do. 50° - 50 do.

Or, supposing the diameter line AC of circle ABCD, or the base of any plane right-angled triangle, to be horizontal,

Then the

Cosines, Versed Sines, and Cotangents will be horizontal,
Sines, Coversed Sines and Tangents will be perpendicular,
Secants will be diagonals extending from centre to Tangent line,
Cosecants do. - do. - do. - - do. Cotangent line.

Or, referring to Fig. 1, and to angles
60° on left hand; and 40° on right hand quadrant.

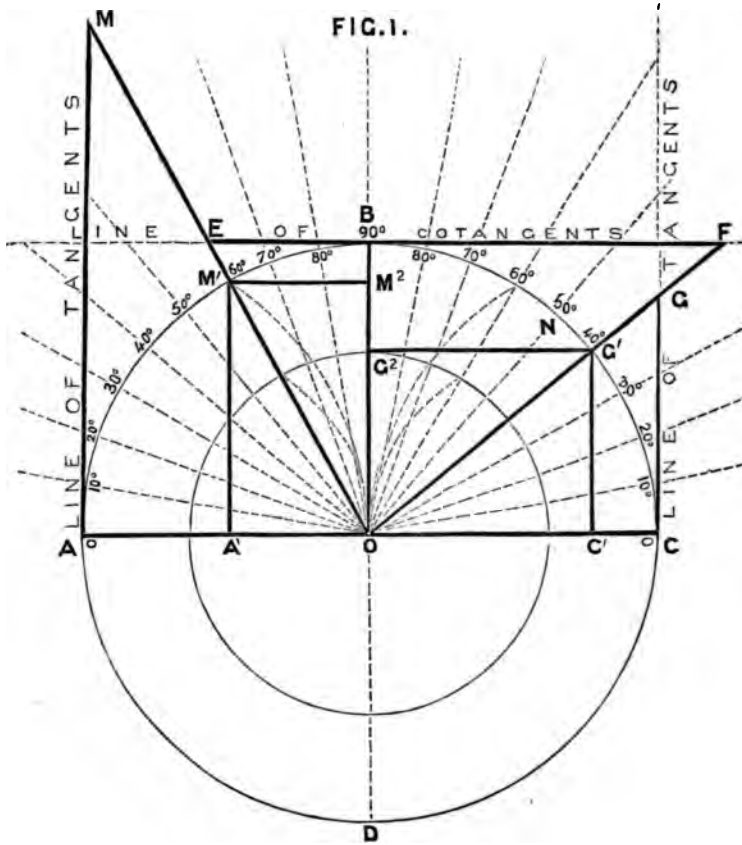
FIG. 1.
M
E
B
90°
F
G
N
M'
M²
C'
C²
A
A'
O
C'
C
D
LINE OF TANGENTS
LINE OF COTANGENTS
LINE OF TANGENTS
10°
20°
30°
40°
50°
60°
70°
80°

On the supposition that the diameter line AC is horizontal, the horizontal lines will be for

ANGLE 60°	ANGLE 40°
Cosine from - - A′ to O	Cosine from - - O to C′
Versed Sine from A to A′	Versed Sine from C′ to C
Cotangent do. E to B	Cotangent do. B to F

The vertical lines, or lines perpendicular to AC will be for

ANGLE 60°	ANGLE 40°
Sine from - - - A′ to M′	Sine from - - - C′ to G′
Coversed Sine from M^2 to B	Coversed Sine from G^2 to B
Tangent - - do. A to M	Tangent - - do. C to G

The lines diagonal to AC will be for

ANGLE 60°	ANGLE 40°
Secant from - - O to M	Secant from - - O to G
Cosecant from - - O to E	Cosecant from - - O to F

And as Cosines, Versed Sines, Cotangents,
Sines, Coversed Sines, Tangents,
Secants, and Cosecants,

are set out from a radius represented by the hypothenuse of any right angled triangle whose three points just meet the circumference of circle described by that radius.

So, for any given radius, and any angle,

As Cosine	: Sine	::	{ Radius, or Hypothenuse }	: Tangent
As Sine	: Cosine	::	Radius	: Cotangent
As Cosine	: Radius	::	Radius	: Secant
As Sine	: Radius	::	Radius	: Cosecant

The difference between Radius and Sine being Coversed Sine
- - do. - - do. - - Cosine being Versed Sine

And, as Tables of natural sines for every degree and minute in the quadrant of a circle are calculated by mathematicians for Radius 1; and the degrees, half-degrees, and equivalents on lines of instrument marked

CO. SINES, SINES, NUMBERS

are set out from those tables; so, approximately, the natural sines for Radius 1 are obtainable from the instrument, and for any other radius by simple multiplication.

That is, for any other radius, which, to distinguish, call "new radius."

Cosine for Rad. 1 × new Radius = Cosine for new Radius
Sine - - do. × - do. - = Sine - - do. - -

And, from the Cosine and Sine for the new radius, the other lines for that radius are obtainable as follow:—

1st Sine - ÷ Cosine × Radius = Tangent
2nd Cosine - ÷ Sine × do. = Cotangent
3rd Radius² ÷ Cosine - - - = Secant
4th do. - ÷ Sine - - - - = Cosecant

Or, by the Instrument

1st (Sine on A − Cosine on N or B) + Radius on N or B =Tangent on A
2nd (Cosine on A − Sine on N or B) + Radius on N or B =Cotangent on A
3rd Radius squared on A − Cosine on N or B = Secant on A
4th - do. - - A − Sine - - do. = Cosecant do.

EXAMPLES.

Required the Cosine, and Sine, of Angle 37° for Radius 1.

Opp. 37° on line CO. SINES is nearly ·799 on line NUMBERS
- do. - SINES - do. - ·602 - - do. - -

Ex. 2nd.—Required the Sine, Cosine, Tangent, Cotangent, Secant, and Cosecant of Angle 37°, for Radius 9.

Now, from example 1st, it is seen that for Radius 1 the

Sine of 37° is nearly ·602
Cosine of - do. - ·799

Therefore, ·602 × Radius 9, and ·799 × Radius 9, or

·602 on A+9 (Radius) on N or B=5·42 nearly for Sine of 37°
·799 on A+9 (Radius) on N or B=7·19 do. Cosine of 37° when the Radius is 9; and

(Sine 5·42 on A − Cosine 7.19 on N or B) + 9 (Radius) on N or B = Tangent 6·78 on A
(Cosine 7·19 on A − Sine 5·42 on N or B) + 9 (Radius) on N or B = Cotangent 11·9 on A
Radius (9) squared, or 81 on A, − 7·19 (Cosine) on N or B = Secant 11·25 on A
Radius (9) squared, or 81 on A, −5·42 (Sine) on N or B = Cosecant 15· on A

That is, the Answers for Angle 37° and Radius 9 are

Sine of Angle 37°	=	5·42	very	nearly	
Cosine - do. -	=	7·19	- do.	-	
Tangent do. -	=	6·78	- do.	-	
Cotangent do. -	=	11·9	- do.	-	
Secant - do. -	=	11·25	- do.	-	
Cosecant do. -	=	15.	- do.	-	

and, for the same Angle 37°, and Radius 9

Radius 9 − Cosine 7·19, gives Versed Sine 1·81
Radius 9 − Sine 5.42, gives Coversed do. 3·58

Ex. 3.—The Cosine, or Base of a Right-angled Triangle is 12
The Sine, or Perpendicular for - do. - is 8
Required the Hypothenuse, or Radius, and the Angle.

In 1st place,

From the properties of Right-angled Triangles, the

Base ^{2} + Perpendicular ^{2} = Hypothenuse ^{2}

or, $\sqrt{}$ (Base ^{2} + Perpendicular ^{2}) = Hypothenuse; or

12 (Base) on D is opp. its Square 144 on A or C
8 (Perpend.) D - - do. - - 64 - do. - } = Sum 208

And 208 on A or C is opp. its Square Root, or Answer nearly 14·42 on D.

Or, to apply the Instrument to Trigonometrical Questions of Oblique-angled Plane Triangles.

PROBLEM I.

Given a side and its opposite angle, together with another side or angle, to determine the Triangle.

RULE—As any one side : sine of its opposite angle
So is any other side : sine of its opposite angle.

Or, by Slide Rule

The 1st Term on N or B set to the 2nd Term on A
opp. 3rd do. - - do. - - 4th - do. - = Answer

Example.—Two angles of an oblique-angled plane triangle being 50° and 68°, and the side opposite to the last angle 500, it is required to determine the Triangle.

In the 1st place 50° + 68° = 118°, and 180° − 118° = 62° for the remaining angle in the given triangle; and as from the instrument—

68° on line Sines is opp. ·927 nearly on Numbers line
50° - do. - do. - ·766 - - do. - -
And 62° - do. - do. - ·883 - - do. - -

Then ·927 on N or B set to the side 500 on A
Opp. ·766 - do. - is the side 413 very nearly on A
·883 - do. - - do. - 476 - do. - do.
Or, the three sides of the Triangle 500, 413, 476
opposite the three Angles - - - 68°, 50°, 62° } = Ans.

PROBLEM II.

Given two sides and the included angle of an oblique-angled plane Triangle, to find the remaining angles and side.

RULE—As the sum of the two given sides
Is to the difference of those sides,
So is the tangent of half the sum of
their opposite angles
To the tangent of half their difference.

The half sum + the half difference = the greater angle
Do. - — - - - do. - - = the lesser do.
And the remaining side of the triangle is found by Problem I.

And innumerable calculations in Trigonometry being greatly facilitated by the use of Tables, the following is given of

TANGENTS AND COTANGENTS FOR RADIUS 1.

Degrees.	Tangents		Cotangents		Degrees.	Tangents		Cotangents	
	0′	30′	0′	30′		0′	30′	0′	30′
0	0000	·00873	Infinite	114·5886	23	·4245	·4348	2·3558	2·2998
1	·0175	·0262	57·29	38·1885	24	·4452	·4557	2·2460	2·1943
2	·0349	·0437	28·6363	22·9038	25	·4663	·4770	2·1445	2·0965
3	·0524	·0612	19·0811	16·3499	26	·4877	·4986	2·0503	2·0057
4	·0699	·0787	14·3007	12·7062	27	·5095	·5206	1·9626	1·921
5	·0875	·0963	11·4301	10·3854	28	·5317	·543	1·8807	1·8418
6	·1051	·1139	9·5144	8·7769	29	·5543	·5658	1·804	1·7675
7	·1228	·1317	8·1443	7·5958	30	·5774	·5890	1·7321	1·6977
8	·1405	·1495	7·1154	6·6912	31	·6009	·6128	1·6643	1·6319
9	·1584	·1673	6·3138	5·9758	32	·6249	·6371	1·6003	1·5697
10	·1763	·1853	5·6713	5·3955	33	·6494	·6619	1·5399	1·5108
11	·1944	·2035	5·1446	4·9152	34	·6745	·6873	1·4826	1·4550
12	·2126	·2217	4·7046	4·5107	35	·7002	·7133	1·4281	1·4019
13	·2309	·2401	4·3315	4·1653	36	·7265	·74	1·3764	1·3514
14	·2493	·2586	4·0108	3·8667	37	·7536	·7673	1·3270	1·3032
15	·2679	·2773	3·7321	3·6059	38	·7813	·7954	1·2799	1·2572
16	·2867	·2962	3·4874	3·3759	39	·8098	·8243	1·2349	1·2131
17	·3057	·3153	3·2709	3·1716	40	·8391	·8541	1·1918	1·1708
18	·3249	·3346	3·0777	2·9887	41	·8693	·8847	1·1504	1·1303
19	·3443	·3541	2·9042	2·8239	42	·9004	·9163	1·1106	1·0913
20	·364	·3739	2·7475	2·6746	43	·9325	·949	1·0724	1·0538
21	·3839	·3939	2·6051	2·5386	44	·9657	·9827	1·0355	1·0176
22	·404	·4142	2·4751	2·4142	45	1·	1·0176	1·	·9827

Or, 90° − The Tangent of any angle being = the Cotangent of that Angle.

90° − The Cotangent of any angle being = the Tangent of that Angle.

The Tangents and Cotangents for every degree and half degree in the quadrant of a circle can be readily obtained from the above Table.

Tangent of 65° being equal to Cotangent 25° = 2·1445 and
Cotangent of 75° - do. - Tangent 15° = ·2679

Ex.—The sides of a Triangle are 90 and 120, and the included angle is 104°; required the other two angles, and the remaining side.

Now to calculate the above and the following examples (which are taken from pages 340, 342 of the twelfth edition of "Nesbit's Mensuration") by the preceding Table and Slide Rule, instead of by Log. Sines used by Nesbit,

In 1st place—

120 + 90 gives 210 for the sum of the two given sides
120 − 90 gives 30 for the difference - do. - -

and $\frac{180° - 104°}{2}$ or $\frac{76°}{2}$ or 38° gives half the sum of the unknown angles.

2ndly—From the Table, the Tangent of 38° = ·7813; and As 210 : 30 :: ·7813 : ·1116; Or, by Slide Rule

210 on N or B set to 30 on A

Opp. ·781 on N or B is ·1116 on A = Tangent of half the difference 6° 22′ between the unknown angles.

3rdly—Half the sum of unknown angles being 38°
Half the difference of do. - - - 6° 22′
38° + 6° 22′ = greater angle 44° 22′
38° − 6° 22′ = lesser do. 31° 38′

Lastly—Lesser side 90 being opp. the lesser Angle 31° 38′ = Sine ·524,

and the longest side opp. the greatest Angle 104°= Cosine 14° = ·97

Then, ·524 on N or B set to 90 on A
opp. ·97 - do. is 166·5 on A for the largest side=Ans.

PROBLEM III.

Given the three side of an Oblique-angled Plane Triangle, to find the Angles.

1stly—As the base, or longest side : the sum of the other two sides

So is the difference of these two sides : difference of segments of base made by a perpendicular from its opp. angle.

$$\text{2ndly}—\frac{\text{The base} + \text{the last difference}}{2} = \text{greater segment.}$$

3rdly—The base − the greater segment=lesser segment.

Example.—The sides of a Triangle are 184, 140, and 92; required the angles.

In 1st place, 184 or longest side, being made the base

140 + 92 = 232 sum of the other two sides
140 − 92 = 48 difference of - do. -

And as 184 : 232 :: 48 : difference of segments of base.

Or, by Slide Rule:—

184 on N or B set to 232 on A
opp. 48 - - do. - - 60·5 nearly on A for difference of segments.

$$\text{2ndly.} \quad \frac{184 + 60{\cdot}5}{2} = \frac{244{\cdot}5}{2} = 122{\cdot}25 \text{ for greater segment}$$

and 184 − 122·25 = 61·75 for lesser do.

Or, the figure is resolved into two right-angled Triangles, one having a radius or hypothenuse 140, and base 122·25; the other having do. - - do. - - 92, and base 61·75; from which the angles of the given triangle are obtainable as follows:—

1stly.—The lines Cosines and Sines, on the instrument, being prepared for Radius 1.

The radius 140 to base or cosines 122·25, being 1 to ·875
Do. 92 - - do. - - 61·75, - 1 to ·671

·875 on Numbers line is opposite to 61° 3′ on Sines line
·671 - - do. - - do. - - 42° 10′ - do. -

The sum of the two=103° 13′ is the angle opposite the base 184
90° — 61° 3′ = 28° 57′ - do. - hypothenuse 92
90° — 42° 10′= 47° 50′ - do. - - do. - 140
Or, 103° 13′; 28° 57′; and 47° 50′ are the required angles.

Or, suppose the three sides of a Right-angled Triangle 160, 110, and 80, are given to find the Angles.

In this example the longest side being 160, then 160 is the Hypothenuse, or Radius.

The proportion of longest other side to Radius 160 is
As 110 to 160, or Radius 1 to ·6875
The proportion of shortest side to Radius 160 is
As 80 to 160, or Radius 1 to ·5

And as Radius 1· on the Rule represents Sine of Angle 90°
and ·6875 on the Rule represents Sine of Angle 43° 25′ nearly
and ·5 - - do. - - do. - - do. - 30°
the required Angles are 90°; 43° 25′ nearly; and 30°

The preceding applications of proposed Instrument to elementary operations being clearly understood; attention is

next directed to what are usually termed "constants," or "gauge points," multipliers, and divisors, for reducing figures of one denomination to another. For instance,

12 pence being	=	1 shilling
12 inches	=	1 foot
20 shillings	=	1 pound
20 cwts.	=	1 ton;

the "constant" or "gauge point" is

12 Multiplier for reducing shillings to pence, or feet to ins.
12 Divisor for reducing pence to shillings, or inches to feet.
20 Multiplier for reducing pounds to shillings, or tons to cwts.
20 Divisor for reducing shillings to pounds, or cwts. to tons.

and so on; and it is essential, in using Slide Rules for calculations, to have numerous well-arranged authentic tables of "Constants," or "Gauge Points," referring to

Money, Weight, Measure, Time, &c., &c.,

in order to obtain speedily, practical answers.

What is commonly designated "Routledge's Engineer's Slide Rule" contains four sets of "Gauge Points"

1st.—For finding the contents in cubic inches, cubic feet, and imperial gallons; also the weight in pounds, of materials specified in the columns under headings Square, Cylinder, Globe

2nd.—For finding areas of Polygons from 5 to 12 sides,
3rd.— - do. - proportions of circles;
4th.—For Pumping Engines.

And, as the figures, divisions, &c., are similar on the lines A, B, C, D, of Routledge's, Soho, and numerous other instruments, to the one now proposed, so the said gauge points apply to all such instruments, and together with the following, mainly derived from data in "Rules and Tables" published by the late eminent Professor Rankine, will be found useful.

GAUGE POINTS FOR CONVERTING BRITISH MONEY INTO FRENCH, &c.

Names.	Farthgs.	Pence.	Shillgs.	Pounds.	Centimes.	Francs.
1 Farthing	1	·25	·0208	·01041	2·627	·02627
1 Penny	4	1·	·0833	·04166	10·5	·10508
1 Shilling	48	12	1·	·05	126·1	1·261
1 Pound	960	240	20	1·	2522·	25·22

FRENCH MONEY AND BRITISH EQUIVALENTS.

Names.	Centms.	Francs.	Farthings.	Pence.	Shillgs	Pounds.
1 Centime	1	·01	·38065	·09516		
1 Franc	100	1·	38·065	9·51625	·79302	·03965

And to find equivalents for any of the above denominations by Slide Rule

Unity of the given denomination on N or B set to its equivalent on A, the lines thus set form tables of equivalents for the respective denominations to which they refer, to any extent.

To convert British money into French, and contrary.

Ex. 1st.—How many Francs are there in 1080 Farthings?

From 1st Table, 1 Farthing = ·02627 Francs
2nd Table, 1 Franc = 38·065 Farthings

Arithmetically,

1080 × ·02627; or 10·80 × 2·627
or 1080 ÷ 38·065 ; or 108·0 ÷ 3·8065

Or, by Slide Rule,

10·8 on A + 2·63 on N or B
or 108· on A − 3·81 on N or B
} = Ans. nrly. 28·4 on A.

Exs. 2, 3, &c.—Required the Francs in 343 Shillings and the Shillings in 842 Francs.

From 1st Table, 1 Shilling = 1·261 Francs
2nd Table, 1 Franc = ·793 Shillings

Arithmetically,

343×1·261; or 343÷ ·793=Answer in Francs
842× ·793; or 842÷1·261=Answer in Shillings

Or, by Slide Rule,

343 on A + 1·261 on N; or 343 on A − ·793 on N gives nearly 432 on A,
and 842 on A + ·793 on B; or 842 on A − 1·261 on B gives nearly 668 on A, for Answer.

Exs. contd.—Required the Francs in £1 15s., and £8 7s.; and the Pounds in 28, and 117 Francs.

Now by using the Line N for Shillings, B for Pounds, and A for Francs; and setting 1 (for one shilling) on N to 1·261 (for 1·261 Francs) on A; and setting 1 (for one Pound) on B to 25·2 (for 25·22 Francs) on A; then for

1st Ex.—Opp. 35 (Shillings) on N is Ans. very nearly 44·2 Francs on A
2nd Ex.—Opp. 167 (Shillings) on N is Ans. - - 211 Francs on A
3rd Ex.—Opp. 28 (Francs) on A is Ans. - - - 1·11 Pounds on B
4th Ex.—Opp. 117 (Francs) on A is Ans. - - - 4·63 Pounds on B
and so on for any amount.

LONG MEASURE.

BRITISH TERMS AND FRENCH EQUIVALENTS.

Names.	Inches.	Feet.	Yards.	Metres.	Kilometres
1 Inch . . .	1	$\frac{1}{12}$	$\frac{1}{36}$	·0254	—
1 Foot . . .	12	1	$\frac{1}{3}$	·3048	—
1 Yard . . .	36	3	1	·9144	—
1 Fathom . .	72	6	2	1·8288	—
1 Pole, or Perch	—	16·5	5·5	5·0291	—
1 Chain . .	—	66	22	20·1166	—
1 Furlong . .	—	—	220	201·166	—
1 Mile . .	—	—	1760	1609·3296	1·6093
1 League . .	—	—	5280	4828·	4·828

FRENCH TERMS AND BRITISH EQUIVALENTS.

Names.	Metres.	Inches.	Feet.	Yards.	Miles.
1 Millimetre	$\frac{1}{1000}$ or ·001	·03937	—	—	—
1 Centimetre	$\frac{1}{100}$ or ·01	·3937	—	—	—
1 Decimetre .	$\frac{1}{10}$ or ·1	3·937	·32809	—	—
1 Metre . .	1·	39·37	3·2809	1·09363	—
1 Decametre .	10·	—	32.809	10·9363	—
1 Hectometre	100·	—	328·09	109·363	—
1 Kilometre .	1000·	—	—	1093·63	·62138
1 Myriametre	10000·	—	—	10936·3	6·2138

Exs.—Required the Metres in 73 and 95 Yards,
and the Yards in 16 and 27 Metres.

From the above Tables, 1 Yard = ·9144 Metres
- - - - - - - - 1 Metre = 1·09363 Yards; and
1 (for one Yard) set on N or B to ·914 (for ·9144 Metres) on A
or 1 (for one Metre) set on A to 1·09 (for 1·09363 yards) on
N or B;
opp. 73 (Yards) on N or B is Ans. very nearly 66·7 Metres on A
opp. 95 do. - - do. - - do. - - 87 - do. -
opp. 16 (Metres) on A is - do. - 17·5 Yds. on N or B
opp. 27 do. - - do. - - do. - 29·5 - do. -

WEIGHT.

BRITISH (AVOIRDUPOIS) AND FRENCH EQUIVALENTS.

Names.	Grains.	Ozs	Lbs.	Cwts.	Grammes.	Kilogrmes.
1 Grain	1	—	—	—	·0648	—
1 Dram	27·34375	$\frac{1}{16}$	—	—	1·7718	—
1 Ounce	437·5	1	$\frac{1}{16}$	—	28·3495	—
1 Pound	7,000	16	1	·00893	453·59	·45359
1 Quarter	—	—	28	·25	—	12·7006
1 Cwt.	—	—	112	1·	—	50·8024
1 Ton	—	—	2240	20·	—	1,016·048

FRENCH WEIGHTS AND BRITISH EQUIVALENTS.

Name.	Grammes.	Kllgs.	Grains.	Pounds.	Cwts.	Tons.
1 Milligramme	$\frac{1}{1000}$ =·001	—	—	—	—	—
1 Centigramme	$\frac{1}{100}$ =·01	—	—	—	—	—
1 Decigramme	$\frac{1}{10}$ =·1	—	—	—	—	—
1 Gramme	1·	$\frac{1}{1000}$	15·4323	—	—	—
1 Decagramme	10	$\frac{1}{100}$	—	—	—	—
1 Hectogrme.	100	$\frac{1}{10}$	—	—	—	—
1 Kilogramme	1,000	1	—	2·20462	—	—
1 Myriagrme.	10,000	10	—	22·0462	·19684	—
1 Quintal	100,000	100	—	220·462	1·9684	—
1 Tonne	1,000,000	1,000	—	2,204·62	19·684	·9842

Exs.—Required the Kilogrammes in 198 pounds,
and the Pounds - in 173 kilogrammes.

From the Table, 1 pound = ·45359 kilogrammes
- - - - 1 kilog. = 2·20462 pounds.

Arithmetically,

198 × ·45359; or 198 ÷ 2·20462
173 × 2·20462; or 173 ÷ ·45359

Or, by Slide Rule,

198 on A + ·454 on N or B; or 198 on A − 2·2 on N or B
= Ans. on A = 90 kilogs.

173 on A + 2·2 on N or B; or 173 on A − ·454 on N or B
= Ans. on A = 381 lbs.

SUPERFICIAL, OR SQUARE MEASURE.

BRITISH TERMS AND FRENCH EQUIVALENTS.

Names.	Sq. Inches	Square Feet.	Square Yards.	Square Millim.	Square Metres.	Square Decim.
1 Sq. Inch	1	$\frac{1}{144}$	$\frac{1}{1296}$	645·148	0·000645	·0645
1 Sq. Foot	144	1	$\frac{1}{9}$	—	·0929	9·29
1 Sq. Yard	1296	9	1	—	·8361	—
1 Rod of Brickwork, measured on face of Wall one and half bricks thick . .		272	—	—	25·269	—
1 Rood of Masonry measured on face of Wall two feet thick		324	36	—	30·1	—
1 Sq. of Roofing or Flooring . . .		100	—	—	9·29·	—
1 Perch of Land .		272¼	30·25	—	25·292	—
1 Square Chain .		—	484	—	404·678	—
1 Rood, or 40 Perches		—	1210	—	1011·696	—
1 Acre, or 4 Roods		—	4840	—	4046·782	—

FRENCH TERMS AND BRITISH EQUIVALENTS.

Names.	Square Metre.	Square Inches.	Square Feet.	Square Yards.	Acres.
1 Sq. Millimetre	$\frac{1}{1000000}$	·00155	—	—	—
1 Sq. Centimetre	$\frac{1}{10000}$	·15503	—	—	—
1 Sq. Decimetre	$\frac{1}{100}$	15·503	—	—	—
1 Sq. Metre . .	1	—	10·7641	1·196	—
1 Sq. Decametre	100	—	1076·41	119·6	—
1 Sq. Hectometre	10000	—	—	11960·	—
1 Centiare of Land	1	—	—	1·196	—
1 Deciare . . .	10	—	—	11·96	—
1 Are	100	—	—	119·6	—
1 Decare . . .	1000	—	—	1196·	—
1 Hectare . .	10000	—	—	11960·	2 4711

EXAMPLES.

Required the Sq. Metres in 27, 37, and 53 Sq. Feet, and the Sq. Feet in 16, 19, and 31 Sq. Metres.

From Table 1st. 1 Sq. Foot = ·0929 Sq. Metres.
- - Table 2nd. 1 Sq. Metre = 10·7641 Sq. Feet.

Arithmetically,

Square Feet × ·0929 = Square Metres,
Square Metres × 10·764 = Square Feet.

Or, by Slide Rule,

1 (Sq. Foot) set on N or B, to ·0929 (Sq. Metres) on A,
or, 9 (Sq. Feet) - - do. - - to ·8361 - do. - on A,
or, 1 (Sq. Metre) set on A, to 10·76 (Sq. Feet) on N or B;
Opposite
27 Sq. Ft. on N or B, is Ans. nearly 2·51 Sq. Met. on A
37 - - do. - - do. - - 3·44 - do. -
53 - - do. - - do. - - 4·93 - do. -
opp. 16 Sq. Met. on A, is Ans. nearly 172 Sq. Ft. on N or B
19 - do. - - do. - - 205 - - do. - -
31 - do. - - do. - - 334 - - do. - -

Required the Sq. Metres in 162 and 243 Sq. Yards, and the Sq. Yards in 31 and 63 Sq. Metres.

From Table 1st. 1 Sq. Yard = ·8361 Sq. Metres,
- - Table 2nd. 1 Sq. Metre = 1·196 Sq. Yards.

Arithmetically,

Sq. Yards × ·8361 = Sq. Metres
Sq. Metres × 1·196 = Sq. Yards

Or, by Slide Rule,

1 (Sq. Yd.) on N or B, set to ·836 (for ·8361 Sq. Met.) on A.
or 1·2 (for 1·196 Sq. Yds.) on N or B, set to 1 (Sq. Met.) on A.
opp. 162 Sq. Yds. on N or B, is Ans. nearly 135·5 Sq. Met. on A.
opp. 243 - - do. - - do. - - 203 - do. -
opp. 31 Sq. Metres on A, is Ans. nearly 37·1 Sq. Yds. on N or B.
opp. 63 - - do. - - do. - - 75·4 - - do. - -

CUBIC MEASURES FOR SOLIDS AND CAPACITY.

BRITISH TERMS AND FRENCH EQUIVALENTS.

	Names.	Cubic Inches.	Cubic Feet.	Cub. Yds.	Gallons.	Cubic Metres.	Litres.
Circular	1 in. diam. by 1 in. long	·7854	—	—	—	—	—
	1 in. diam. by 1 ft. long	9·4248	—	—	·034	—	—
	1 ft. diam. by 1 in. long	113·0976	·06545	—	·4081	—	—
	1 ft. diam. by 1 ft. long	1357·17	·7854	—	4·897	·0222	22·2
Square	1 in. sq. by 1 in. long	1	—	—	—	—	—
	1 in. sq. by 1 ft. long	12	$\frac{1}{144}$	—	·0433	—	—
	1 ft. sq. by 1 in. long	144	$\frac{1}{12}$	—	·5196	·00236	2·36
	1 ft. sq. by 1 ft. long	1728	1	—	6·235	·0283	28·32
	1 yd. sq. by 1 ft. long	—	9	—	56·119	·2548	254·85
1 Rod of Brickwork 13½ in. thick, 272 sq. ft. on face		—	306	11½	—	8·665	—
1 Rood of Masonry 2 ft. thick, 36 sq. yds. on face		—	648	24	—	18·35	—
1 Gill		8·66					
1 Pint		34·64					
1 Quart		69·28	—	—	·25	—	1.135
1 Gallon ("Rankine")		277·123	·16037	—	1	—	4·541
1 Bushel, or 4 Pecks		—	1·283	—	8	—	36·328
1 Quarter, or 8 Bushels		—	10·264	—	64	—	290·625

FRENCH TERMS AND BRITISH EQUIVALENTS.

Names.	Cubic Metres.	Litres.	Cubic Inches.	Cubic Feet.	Cub. Yds.	Gallons.
1 Millilitre	—	·001	—	—	—	—
1 Centilitre	—	·01	—	—	—	—
1 Deciletre	—	·1	—	—	—	—
1 Litre	$\frac{1}{1000}$	1	61·025	·035316	—	·22021
1 Decalitre	$\frac{1}{100}$	10	—	·35316	—	2·2021
1 Hectolitre	$\frac{1}{10}$	100	—	3·5316	—	22·0215
1 Kilolitre	1	1000	—	35·316	—	220·215

EXAMPLES.

Required the Cubic Metres in 53, 72, 84, and 96 Cubic Feet, and the Cubic Feet in 5·3, 7·2, 8·4, and 9·6 Cubic Metres.

From

Table 1st. 1 Cubic Foot = ·0283 Cubic Metres
Table 2nd. 1 Cubic Metre = 35·316 Cubic Feet

And, by Slide Rule,

1 (Cub. Ft.) on N or B, set to ·0283 (Cub. Met.) on A
Or 100 - do. - - - do. - - 2·83 - - do. - on A
Or 1 (Cub. Met.) on A, set to 35·316 (Cub. Ft.) on N or B.

Then,

Opp. 53 Cub. Ft. on N or B, is Ans. nrly. 1·5 Cub. Met. on A
- 72 - - do. - - - do. - - 2·04 - do. - -
- 84 - - do. - - - do. - - 2·38 - do. - -
- 96 - - do. - - - do. - - 2·72 - do. - -
- 5·3 Cub. Met. on A, is Ans. nrly. 187 Cub. Ft. on N or B
- 7·2 - - do. - - do. - - 254 - - do. - -
- 8·4 - - do. - - do. - - 297 - - do. - -
- 9·6 - - do. - - do. - - 339 - - do. - -

Required the Litres in 9, 13, and 19 Gallons, and the Gallons in 9, 13, and 19 Litres.

From Table 1st. 1 Gallon = 4·541 Litres
Table 2nd. 1 Litre = ·2202 Gallons

And by Slide Rule,

1 (Gallon) on N or B, set to 4·54 (Litres) on A
Or, 1 (Litre) on A, set to ·22 (Gallon) on N or B,

Then

Opp. 9 Gallons on N or B, is Ans. nrly. 40·8 Litres on A
- 13 - - do. - - - do. - - 59· - do. -
- 19 - - do. - - - do. - - 86·3 - do. -
- 9 Litres on A, is Ans. nrly. 1·98 Gallons on N or B
- 13 - do. - - do. - 2·86 - - do. - -
- 19 - do. - - do. - 4·18 - - do. - -

Or, with the Slides thus set, any number of Litres on **A** will be opposite the corresponding number of Gallons on **N** or **B**, and contrary.

PRESSURE.

BRITISH TERMS AND FRENCH EQUIVALENTS.

Names.	Pounds.				Kilogrammes.	
	Per Cir. In.	Per Cir. Ft.	Per Sq. In.	Per Sq. Ft.	Per Sq. Centim.	Per. Sq. Decim.
Water Column 1 in. high	·02834	4·081	·03608	5·196	·002537	·2537
- Do. - 1 ft. „	·34	48·973	·433	62·355	·030444	3·044
- Do. - 2·309 „	·7854	113·097	1·	144·	·07030	7·03
- Do. - 2·94 „	1·	144·	1 2732	183·34	·08951	8·951
- Do. - 1 yd. „	1·02	146·92	1·299	187·06	·09133	9·133
Mercury Col. 1 in. „	·3857	55·55	·491	70·73	·03452	3·452
- Do. - 1 ft. „	4·6284	666·6	5·894	848·75	·4143	41·43
- Do. 29·92 in. „	11·545	1662·5	14·7	2116·8	1·033	103·3

FRENCH TERMS AND BRITISH EQUIVALENTS.

Names.	Kilogrammes.				Pounds.	
	Per Cir. Centim.	Per Cir. Decim.	Per Sq. Centim.	Per Sq. Decim.	Per Cir. In.	Per Sq. In.
Water Col. 1 Metre high	·07845	7·845	·0998	9·98	1·116	1·4207
1 Kilog. per sq. Millim.	78·54	7854·	100·	10000·	1117·08	1422·31
- Do. - Centim.	·7854	78·54	1·	100·	11·17	14·223

And the terms of pressure multiplied by any vertical height lifted, as

Pounds × height lifted in Feet, is expressed in Foot Pounds
Tons - × - - do. - - do. - - do. - Foot Tons
Kilogs. × - - do. - - Metres, - do. - Kilogrammetres

120 Pounds lifted 3 Feet being $120 \times 3 = 360$ Foot Pounds
120 Tons - - - do. - - $120 \times 3 = 360$ Foot Tons
120 Kilogs. - - 3 Metres - $120 \times 3 = 360$ Kilogrammetres

1 Foot Pound being = ·13825 Kilogrammetres
1 Kilogrammetre = 7·233 Foot Pounds

Or Again, 33000 Pounds weight lifted 1 ft. per minute
Or, 3300 Gallons of Water lifted 1 ft. per minute
Or, 33 - - do. - - do. - 100 ft. - do. -

represents 1 Horse Power, supposing no power is absorbed by friction.

EXAMPLES.

Ex.—Suppose two Columns of Water:—

One 37 Yards high, and One 18 Metres.

Required the pressure of former in Kilogrammes per Square Decimetre; and of latter in Pounds per Square Inch.

From Table 1st, A Column of Water 1 Yard high = 9·133 Kilogrammes per Square Decimetre.

From Table 2nd, A Column of Water 1 Metre high = 1·4207 Pounds per Square Inch.

Arithmetically,

37 Yards × 9·133 = Kilogs. per Square Decimetre,
18 Metres × 1·4207 = Pounds per Square Inch.

Or, by Slide Rule,

1 (Yard) on N, set to 9·13 (Kilogs.) on A
and 1 (Metre) on B, set to 1·42 (Pounds) on A

Opp. 37 Yards on N, is Answer nearly 338 Kilogs. per Square Decimetre on A; and

Opp. 18 Metres on B, is Answer on A, very nearly 25·6 Pounds per Square Inch.

Ex.—Required the height in Feet of two Columns of Water, one to give a pressure of 19 Pounds per Square Inch, and one - do. - - do. - 18 Kilogs. per Square Decimetre.

From Table 1st, Water Column 2·309 Feet high = 1 Pound per Square Inch.

Do. do. Water Column 2·309 Feet high = 7·03 Kilogs. per Square Decimetre.

Arithmetically,

2·309 × 19 = 43·8 height in Feet for 19 Pounds per Sq. Inch

And (2·309 ÷ 7·03) × 18 = 5·91 height in Feet for 18 Kilogs. per Square Decimetre.

Or, by Slide Rule,

2·31 (for 2·309) on A + 19 on N = Ans. 43·8 on A in Feet.

And (2·31 on A − 7·03 on B) + 18 on B = Ans. 5·91 on A do.

Or in the last of the last two examples, the Answer gives a Column of Water 5·91 Feet high, as pressing on a surface of Square Decimetre (15·5 Square Inches) with 18 Kilogrammes, or very nearly 39·7 Pounds, or about 2·55 Pounds per Square Inch.

HEAT.

The Instrument most commonly used for measurement of Temperature, is

Fahrenheit's Mercurial Thermometer in England,
Centigrade - - do. - - do. - - France,
Reaumur's - - do. - - do. - occasionally abroad,

the arbitrary scale of each indicating a certain number of divisions, or degrees, between the surface marks of

Mercury representing the temperature of melting ice;
and - Do. - - do. - - boiling point of water under atmospheric pressure.

Thus,

The Boiling Point = 212° Fah. ;=100° Centi. ;=80° Reaum.
- Freezing do. = 32° do. = 0° do. = 0° do.
- Difference - - 180° do. =100° do. =80° do.

Or, reckoning from the respective ice melting points of the various Thermometers.

9° Fah. = 5° Centi. = 4° Reaum.
1° do. = $\frac{5}{9}$° do. = $\frac{4}{9}$° do.

$$\frac{\text{Fahrenheit Degrees} \times 5}{9} = \text{Degrees Centigrade}$$

$$\frac{\text{Fahrenheit Degrees} \times 4}{9} = \text{Degrees Reaumur}$$

$$\frac{\text{Centigrade Degrees} \times 9}{5} = \text{Degrees Fahrenheit}$$

$$\frac{\text{Reaumur Degrees} \times 9}{4} = \text{Degrees Fahrenheit}$$

Or, by Slide Rule,

5° (Cent.) on N, set to 9° (Faht.) on A
and 4° (Reaum.) on B, set to 9° (Do.) on A
opposite any number of Fahrenheit Degrees on A
is the corresponding - do. - Centigrade - do. - on N
and - - do. - - do. - Reaumur - - do. - on B

Exs.—Required the temperature in Fah. Degrees corresponding with — 8° Centigrade and — 8° Reaumur.

In these examples, the minus sign — shows that the temperature is as much below zero as the figures represent; and as the Centigrade and Reaumur Zero, or 0°, corresponds with freezing point, while the Zero of Fahrenheit is 32° below its freezing point, so it rarely happens that the sign — requires to be used for Fah. Degrees.

But to the questions.—With the slides N, B set as described

viz., 5 (Cent. Degrees) on N to 9 (Fah. Deg.) on A
4 (Reau. do.) - B to 9 (do.) on A

opp. 8 (Cent. Degrees) on N is 14·4° Fah. on A below Fah. freezing point.

opp. 8 (Reaumur Degrees) on B is 18 Fah. on A below Fah. freezing point.

Or 32° − 14·4° or 17·6° Fah. corresponds with −8° Centigrade
32 −18· - 14· do. - - do. - - −8° Reaumur.

Again, the term "Unit of Heat" is applied

in England to one pound of Water heated 1° Fah.
in France to one kilogramme of Water heated 1° Centigrade
Or, 1 British Unit of Heat is

$$\frac{1 \times 5}{2{\cdot}2046 \times 9} = \frac{5}{9{\cdot}84161} = \text{nearly } {\cdot}252 \text{ French Units,}$$

1 French Unit is

$$\frac{2{\cdot}2046 \times 9}{1 \times 5} = \frac{19{\cdot}8416}{5} = \text{nearly } 3{\cdot}9683 \text{ English Units}$$

Or, by Slide Rule—

1 (British Unit) set on N to ·252 French Units on A
and 1 (French Unit) - B to 3·97 British Units on A

with the slides thus set, the figures and divisions on N, B, represent British and French units of heat, opposite their corresponding equivalents on A, to any extent.

Exs.—Required the French Units of heat in 19 British Units
and the British - do. - 19 French Units

Here, 1 (British Unit) on N set to ·252 French Units on A
and 1 (French Unit) on B do. 3·97 British Units on A
opp. 19 (British Units) on N is nearly 4·8 French Units on A.
opp. 19 (French Units) on B is nearly 75·5 British Units on A.

UNIFORM MOTION.

Rates of Speed.	Per Minute.		Per Hour.	
	Feet.	Yards.	Yards.	Miles.
1 foot per second	60	20	1200	·6818
1 yard per second	180	60	3600	2·0454
1 mile per hour	88	29⅓	1760	1·

Or, a carriage wheel 3 ft. 6 in. diameter making 480 revolutions per minute, without slipping, will pass over one mile of road, reckoning the circumference of wheel in proportion to its diameter as 22 to 7.

Or, to find the revolutions made by any carriage wheel travelling one mile of road, without slipping—

Divide 480 by the diameter, and the product of quotient multiplied by 3·5 will give the Answer, reckoning the diameter in feet.

Or, by Slide Rule

(480 on A — given diameter on N or B) + 3·5 (constant) on N or B

Or, given diameter on N or B, set to 480 on A opposite 3·5 on N or B, is Answer on A.

Ex. 1.—Suppose a wheel 5 ft. diameter runs without slipping over one mile of road; required the revolutions.

(480 on A — 5 on N or B) + 3·5 on N or B;
or, 5 on N or B, set to 480 on A
opp. 3·5 on N or B is Ans. 336 revolutions on A.

Ex. 2.—Required the diameter of a Locomotive driving wheel to make 320 revolutions per mile, supposing no slip.

(480 on A − 320 on N or B) + 3·5 on N or B, gives the answer in feet 5·25 on A.

Or, 320 on N or B, set to 480 on A
opp. 42 (ins.) on N or B gives the diameter on A = 63 inches.

ACCELERATED MOTION.

For bodies falling freely, and meeting with no resistance from the atmosphere; when the

Time of Vertical Descent given in Seconds.
Distance - - - do. - - - Feet.
Gravity - - - 32·2 - - -

1st.—To find the height fallen when the time of descent is given.

Rule.—The time squared × by 16·1 = Ans.

Or, by Slide Rule,

The Time on D being opposite its Square on A,
The Square on A + 16·1 on B = Answer.
Or, 1 on D set to 16·1 on $\frac{B}{C}$
Opposite the Seconds on D is Answer on $\frac{B}{C}$

Ex.—Required the vertical Descent of heavy bodies falling freely 4 seconds.

4 on D is opposite its Square 16 on A,
And 16 on A + 16·1 on B = 257·6 Feet on A;

Or, 4 on D + 16·1 on $\frac{B}{C}$;
Or, 1 on D set to 16·1 on $\frac{B}{C}$,
Opp. 4 on D, is the Answer nearly 258 Feet on $\frac{B}{C}$

2nd.—To find the vertical Descent during each Second of fall.

RULE.—Multiply 16·1 by one less than the number of half seconds occupied by the body in falling freely from the commencement of its descent to the end of the second under consideration, and the product will give the Answer.

Or, by Slide Rule,

16·1 on A + (Half Seconds − 1) on N or B = Answer on A.

Or, 1 on N or B set to 16·1 on A

Opp. (Half Seconds − 1) on N or B is the Answer on A as before.

Ex.—Suppose a heavy body falls freely 3 seconds, what is its descent during each second?

From the commencement of fall to latter end of

1st second of descent = 2 half-seconds

2nd - - do. - - = 4 - do. -

3rd - - do. - - = 6 - do. -

2 − 1 = 1; 4 − 1 = 3; 6 − 1 = 5; therefore

1 on N or B, set to 16·1 on A,

opp. 1 - do. - is 16·1 on A, for descent during 1st second

3 - do. - - 48·3 - do. - - do. - 2nd do.

5 - do. - - 80·5 - do. - - do. - 3rd do.

Or, the sum = 144·9 ft. represents very nearly the whole descent during 3 seconds.

3rd.—To find the time of descent of a heavy body falling freely from any given height in feet.

RULE.—Divide the height by 16·1, and the Square Root of quotient will give the Answer.

Or, by Slide Rule,

Height on A − 16·1 on $\frac{B}{C}$,

Or, 16·1 on $\frac{B}{C}$ set to height on A,

Opp. 1 on $\frac{B}{C}$ is the Answer very nearly in seconds on D.

Ex.—Vertical height of descent being 144 feet; required the time of descent.

Here 144 on A $-$ 16·1 on $\frac{B}{C}$;
Or, 16·1 on $\frac{B}{C}$, set to 144 on A,
Opp. 1 on $\frac{B}{C}$, is very nearly 9 on A, and its Square Root nearly 3 on D.
The Answer is therefore nearly 3 seconds.

4th.—To find the velocity acquired by a heavy body falling freely any given number of seconds.

Rule.—Multiply 32·2 by the time in seconds for Answer.

Or, by Slide Rule,

32·2 on A $+$ seconds on N or B,
Or, 1 on N or B, set to 32·2 on A,
Opp. the time on N or B, is Answer on A.

Ex.—When a heavy body falls freely 4 seconds, what is the velocity acquired at the end of that time?

Here—Arithmetically 32·2 $\times$ 4,

or by Slide Rule,

32·2 on A $+$ 4 on N or B.
Or, 1 on N or B, set to 32·2 on A,
opp. 4 on N or B, is 128·8 on A = Answer in feet per second.

5th.—To find the velocity acquired by heavy bodies falling freely from any given height in feet.

Rule.—Multiply the square root of the height by 8·025, and the product will give very nearly the velocity in feet per second.

Or, by Slide Rule,

Any height on A being opposite its square root on D, the last result (taken on A) $+$ 8·025 on N or B, = Answer on A.

Ex.—Required the velocity acquired by a body falling freely a vertical height of 256 feet.

Here, by Slide Rule, 256 on A is opposite its square root 16 on D.

And, 16 on A + 8·025 on N or B = 128·4 on A, for the velocity acquired in feet per second at the end of descent.

6th.—To find the vertical height fallen by heavy bodies when their final velocities are given in feet per second.

Rule.—Divide the square of final velocity by 64·4. Or, divide the final velocity by 8·025 and square the quotient for Answer.

Or, by Slide Rule,

Final velocity on A − 8·025 on N or B = Quotient on A, and the quotient taken on D is opposite its square on A, or Ans.

Ex.—Required the vertical height fallen by a heavy body when its final velocity is at the rate of 376 feet per second.

Here, 376 on A − 8·025 on N or B gives very nearly 46·8 quotient on A, and 46·8 on D is nearly opposite its square 2200 on A; or the Answer is nearly 2200 feet.

And as the product of vertical height from which a heavy body falls, when meeting no resistance from the atmosphere, multiplied by its weight in pounds, or tons, represents stored-up energy

in Foot Pounds
or Foot Tons; then

supposing the body alluded to in last example=68 pounds,

2200 × 68 Arithmetically

Or, by Slide Rule,

2200 on A + 68 on N or B gives nearly 150000 Foot Pounds on A for the stored-up energy, supposing the velocity of weight at time of impact = 376 Feet per Second.

7th.—To find the stored-up energy of a moving mass.

Rule.—Multiply its weight by the half-square of its velocity, and divide that product by gravity (32·2).

Or, divide the product of weight multiplied by the square of its velocity by 64·4.

Or, by Slide Rule

The velocity on D being opposite its square on A, the (square on A − 64·4 on N or B) + weight on N or B = Ans. on A.

Or, To work the last example by this rule.

376 on D is opposite its square very nearly 142000 on A, and (142000 on A − 64·4 on N or B) + 68 on N or B gives nearly 150000 Foot Pounds on A for Ans. as before.

Ex.—Required the actual energy, or stored-up work, in a 68-pdr. shot at the time of impact; supposing its velocity at that time = 1200 feet per second.

Here, 1200 on D is opposite its square 1440000 on A, and (1440000 on A − 64·4 on N or B) + 68 on N or B = 1520000 Foot Pounds nearly on A for the actual energy.

Or, 1520000 ÷ 2240 gives nearly 680 Foot Tons.

PENDULUMS.

A Pendulum vibrating seconds in the latitude of London, being very nearly 39·14 inches long; and Pendulum vibrations in the same latitude, as the Square Roots of their length; then 60 × $\sqrt{39·14}$ gives the constant number 375·36, from which the length of Pendulum making any number of vibrations per minute can be found.

Or, To find the number of vibrations per minute when *length* of Pendulum is given.

Divide 375·36 by the Square Root of the length, or

By Slide Rule,

Any length of Pendulum being on A opposite its Square Root on D,
375·36 (say 375·4) on A — last result on N or B = Ans. on A.

Ex. 1st.—Suppose a Pendulum is to make 50 vibrations per minute, required its length—

Arithmetically $(375{\cdot}4 \div 50)^2$ = Ans.

Or, by Slide Rule, 375·4 on A — 50 on N or B = 7·5 nrly. on A.
7·5 on D is opp. its square 56·25 on A.
56·25 inches is therefore the length of Pendulum.

Ex. 2nd.—Required the number of vibrations made per minute by Pendulum 27 inches long—

27 on D is opp. its Square Root nrly. 5·2 on D

Arithmetically 375·4 ÷ 5·2. Or,

By Slide Rule, 375·4 on A — 5·2 on N or B = 72 nrly. on A for the number of vibrations per minute.

Or, The length of Pendulum making 72 vibrations per min. $= (375{\cdot}4 \div 72)^2$ = nrly. 27 inches.

GOVERNORS.

The same law as for Pendulums applies also to Governors employed for regulating the speed of Steam Engines; one revolution of Governor being made in the same time as two

vibrations of Pendulum whose length is equal to the vertical height from centre of gravity of balls and arms, in plane of revolution, to the point where the centre lines of suspension intersect the axis of spindle.

Or, $375{\cdot}4 \div 2 = 187{\cdot}7 =$ Constant,

$187{\cdot}7 \div \sqrt{}$ vertical height = Revs. of Gov. spindle,

$(187{\cdot}7 \div$ revs. per minute$)^2$ = vertical hght. of arms.

And,

Supposing the arms suspend angles of 30° with axis of spindle when the Governor at its proper speed.

Then,

Vertical hght. $\div {\cdot}866$, or $\times 1{\cdot}154 =$ length of governor arms,

Or,

Length of arms $\times {\cdot}866$, or $\div 1{\cdot}154 =$ vertical height, practically, from the centre of governor balls to the point of suspension, or intersection.

Or,

By Slide Rule,

1st.—When vertical height given in inches to find the revolutions of governor spindle per minute.

Any vertical height on A being opp. its square root on D

$187{\cdot}7$ on A—last result on N or B = revs. per min. on A

2nd.—When the speed is given, to find the vertical height and length of arms whose points of suspension are in the axis of revolution, and angles of suspension with axis are 30° when governor at right speed.

1st.—$187{\cdot}7$ on A—revs. per min. on N or B = 1st result

2nd.—1st result on D is opp. its square on A, or vertical height

3rd.—Vert. hght. on A—$\cdot866$ on N or B = length of arms on A

Ex.—Required the vertical height and length of arms for Governor making 35 revolutions per minute.

$187{\cdot}7$ on A—35 on N = $5{\cdot}36$ on D opp. its sq. $28{\cdot}7$ on A

$28{\cdot}7$ is therefore vert. height, and

$28{\cdot}7$ on A — $\cdot866$ on B = $33{\cdot}1$ ins. on A = length of arms.

To find the SIMPLE INTEREST of any sum of money for any number of years, or days, at any rate per cent. per annum.

1st. { For Years, 1 on N / „ Days, 365 on B } set to { the rate of / Interest on A

Opp. the No. of Years on N / Or do. Days on B } will be { the Interest on A / of £100 for same time.

And 2nd.—100 (£) on N or B set to last result on A
Opp. any sum on do. is the Interest on A = Ans.

Ex. 1st.—Required the simple Interest of £178 for 2 years 160 days at $3\frac{1}{2}$ per cent. per annum.

In 1st place 1 (Year) on N / 365 (Days) on B } set to 3·5 (per cent.) on A

Opp. 2 (Years) on N is £7 on A / „ 160 (Days) on B is 1·53 on A } = { £8·53 for Int. of / £100 the time, &c.

Or, opp. 890 Days on B is £8·53 on A = Int. as before.

And 2nd.—£100 on N or B set to £8·53 on A
Opp. £530 on do. - is £45·2 on A = Ans.

Ex. 2nd.—Required the number of days interest in £13, reckoning on £300 at 5 per cent.

In 1st place, Interest of £300 at 5 per cent. = £15,
Or, 100 on N or B set to £5 on A
Opp. 300 on do. - is £15 on A

2nd.—£15 on N or B set to 365 (days) on A
Opp. £13 on do. - is 316 do. on A = Ans.

And so on for other questions of Simple Interest.

RULES, &c.

1st.—The sum to which £1 with Compound Interest amounts in any number of years, at any rate per cent. per annum, is equal

(£1 + Interest of £1 for one year)

raised to the power expressed by the number of years.

And calling this Answer - - 1st result
and (1st result − 1) - - - 2nd do;

the latter represents the Compound Interest of £1 for the same time and rate.

And, in many instances, the powers of numbers being most readily obtained by Logarithms, the following Table is prepared for sundry rates of interest.

Rate of Interest.	Int. of £1 One Year.	£1 + Int. of £1 One Year.	Logs. of Nos. in 3rd col.
2 per cent.	... ·02 ...	... 1·02 ...	... 0·0086
2½ ...	... ·025 ...	... 1·025 ...	... 0·0107
3 ...	... ·03 ...	... 1·03 ...	... 0·0128
3½ ...	... ·035 ...	... 1·035 ...	... 0·0149
4 ...	... ·04 ...	... 1·04 ...	... 0·0170
4½ ...	... ·045 ...	... 1·045 ...	... 0·0191
5 ...	... ·05 ...	... 1·05 ...	... 0·0212
6 ...	... ·06 ...	... 1·06 ...	... 0·0253
7 ...	... ·07 ...	... 1·07 ...	... 0·0294
8 ...	... ·08 ...	... 1·08 ...	... 0·0334
9 ...	... ·09 ...	... 1·09 ...	... 0·0374
10 ...	... ·1 ...	... 1·1 ...	... 0·0414

Rule 2nd.—The sum to which £1 per annum with Compound Interest amounts in any number of years, at any rate per cent. per annum, is equal quotient of 2nd result ÷ Interest of £1 one year.

Rule 3rd.—The present value of £1 due at the end of any number of years, reckoned at any rate of Compound Interest per cent. per annum = 1 ÷ 1st result.

RULE 4th.—The present value of £1 per annum, payable any number of years, reckoning any rate of compound Interest per cent. per annum, is equal to quotient of 2nd result ÷ (1st result × Int. of £1 one year.)

And RULE 5th.—The results from four preceding rules having been obtained for £1, the product of any of those results multiplied by any sum, will represent the corresponding answer for that sum.

EX. 1st.—Required the sum to which £1 with Compound Interest amounts in 9 years, reckoned at 5 per cent per annum.

From Table last page.	£
Interest of £1 for one year at 5 per cent. =	·05.
Principal £1 + ·05 - - - - - - - - =	1·05.
Logarithm of 1·05 - - - - - - - - =	0·0212.

From RULE 1st.—$1{\cdot}05^9$ = Log. 0·0212 × 9 = Log. 0·1908, and 0·1908 on COM. LOGS. line = 1·551 on NUMBERS line.

Or,

The sum to which £1 with Compound Interest amounts in 9 years at the given rate is £1·551 = 1st result.

1·551 − 1 - - - = £·551 Comp. Int. = 2nd result.

And for £60, these sums × 60 = corresponding Answers.

EX. 2nd.—Required the sum to which £60 per annum with Compound Interest will amount in 9 years, at 5 per cent. per annum.

From Ex. 1st.—2nd result = ·551£; Int. of £1 one year = ·05.
From Rule 2nd.—2nd result ÷ Int. of £1 one year = ·551 ÷ ·05.
Or, ·551 on A − ·05 on N or B = 55·1 on A − 5 on N or B
= £11·02 Ans. for £1,
And, 11·02 on A + 60 on N or B = Ans. £661·2 for £60,

Ex. 3rd.—Suppose a Legacy of £60 due at the end of 5 years; what is its present value, reckoning 4 per cent. compound interest?,

From Rule 3rd, page 76.—The present value of £1, due at the end of five years, reckoning 4 per cent. per annum compound interest to the purchaser for his money, is obtained by dividing £1 by the sum (1st result) to which £1 amounts in the same time at the same rate.

From Table, page 76 £

Column 2nd—The Int. of £1 one year at 4 per cent. = ·04

do. 3rd—Principal £1 + ·04 - - - - - - - = 1·04

do. 4th—Log. of 1·04 - - - - - - - - - - = 0·017

From Rule 1st.—1·04 raised to the power expressed by 5 (years) = $1{\cdot}04^5$ = Log. 0·017 × 5 = Log. 0·085, 0·085 on COM. LOGS. line is opp. 1·217 on NUMBERS line, £1·217 is = 1st result.

From Rule 3rd.—1 ÷ 1·217, or 1 on A − 1·217 on N or B gives ·822£ on A for the present value of £1 legacy.

And

·822 on A + 60 on N or B = £49·32 Ans. for Legacy £60.

Ex. 4th.—Suppose an annuity of £60 has to be paid for 5 years, what is the present value, reckoning the purchaser 4 per cent. compound interest, per annum, for his money.

From Ex. 3.—The sum to which £1 with compound interest amounts in five years at 4 per cent. = 1st result = £1·217

Compound Interest - - - - = 2nd do. = ·217

From Table—Int. of £1 one year at 4 per cent. = ·04

From Rule 4th—·217 ÷ (1·217 × ·04) = ·217 ÷ ·04868 = 21·7 ÷ 4·868 = 21·7 on A − 4·868 on N or B - - - - - - - - - - - - = 4·45 on A

£4·45 is therefore the present value of £1 annuity; and

£4·45 on A + 60 on N or B = £267·6 on A gives the present worth of £60 annuity at the same rate &c. = Ans.

Ex. 5th.—Suppose an annuity of £80 has to be paid for 20 years; required its present value, reckoning the purchaser to have 5 per cent. per annum, Compound Interest.

From Table, page 76.

The Interest of £1 one year at 5 per cent. = ·05.
- Principal £1 + ·05 - - - - - = 1·05.
- Log. of 1·05 - - - - - = 0·0212.

From Rule 1st.—1·05 raised to the power expressed by 20 (years) = $1·05^{20}$ = Log. 0·0212 × 20 = Log. 0·424.
0·424 on COM. LOG^{S}. line is opp. 2·655 on NUMBERS line.
£2·655 is therefore - = - 1st result.
2·655 − 1 = 1·655 - = - 2nd do.

From Rule 4th.—1·655 ÷ (2·655 × ·05) = 1·655 ÷ ·13275,
Or, 16·55 on A − 1·3275 on N or B = £12·5 nearly on A for the present worth of £1 annuity—
And,
12·5 on A + 80 on N or B = nrly. £1000 for £80 annuity.

PROPERTIES OF CIRCLES, SQUARES, ETC.

1st.—When the diam. of a Circle is 1, the circum. being 3·1416; Or, when the diam. of Circle is 7, the circum. being nearly 22; the circumferences of circles being in direct proportion to each other as their respective diameters;
any diam. × 3·1416 gives the circumference,
or, - do. × $\frac{22}{7}$ - do. - - do.
Any circumference ÷ 3·1416 gives the diameter,
any - do. - ÷ $\frac{22}{7}$ - - - do.
Or, by Slide Rule,
7 on N or B, set to 22 on A, the figures and divisions on N or B represent diameters, and the figures and divisions on A represent circumferences, for any dimensions of similar denomination.

2nd.—When the diam. of a circle is 1, the area is ·7854,
or, - - do. - - do. - 10, - do. - 78·54,
and, as the areas of circles are in direct proportion to each other as the squares of their respective diameters,
So, by Slide Rule,
When 1 (diam.) on D is set to ·7854 on C,
or 10 (diam.) on D is set to 78·54 on C,
the figures and divisions on D represent diameters of circles, to which the opposite figures and divisions on C give corresponding areas.

3rd.—When diam. of circle is 1,
The side of least circumscribing square is 1
The diagonal of - do. - - do. is 1·4142
The side of greatest inscribed square is ·7071
The diagonal of do. - - - do. is 1·
The side of a square with same area is ·8862.
When the side of a square is 1, the diameter of a circle with same area is 1·1284. And

4th.—The areas of ovals are equal
Long × short diameters × ·7854; or
Long × short diameters ÷ 1·2732

EXAMPLES.

Showing the application of Slide Rule to above data for circles, &c.

1st.—Required the
Circumferences of Circles 3, 5, 9 inches diameter,
and Diameters of Circles 13, 23, 28 inches circumference.
Here, 7 (diam.) on N or B, set to 22 (circumference) on A
opposite the diameters 3 ; 5 ; 9 inches on N or B,
are the circumferences 9·42; 15·7; 28·3 inches on A.
And opp. the circumferences 13 ; 23 ; 28 on A
are the diameters - - - 4·14; 7·32; 8·91 on N or B.

Or, with the slide N or B thus set,

Any diameter of circle on N or B is opp. its circumference on A
or circumf. - do. - A - do. - diameter on N or B

2nd.—Required the

Areas of Circles 5, 9, 13 inches diameter
and Diams. of do. 20, 30, 40 sq. ins. area.

Here, 1 (diam.) on D set to ·7854 on C;
or 10 - do. - 78·54 (area) on C
Opposite the Diamrs. 5 ; 9 ; 13 on D
are the Areas 19·6 ; 63·6 ; 133 on C and

Opposite the Areas 20 ; 30 ; 40 on C
are the Diameters 5·04 ; 6·18 ; 7·13 on D.

Or, with the slide $\frac{B}{C}$ thus set,

The Areas of any circles are on that slide opposite the Diameters on D.

3rd.—Required the diagonals of least squares that will contain circles 6, 14, 17 inches diameter.

1 (Diam.) on N or B, set to 1·415 (for 1·4142) on A
opposite the diameters 6 ; 14 ; 17 on N or B,
are the diagonals 8·5 ; 19·8 ; 24·05 on A of the least squares that will circumscribe the given circles.

4th.—Required the sides of greatest squares that can be inscribed in circles 6, 11 and 17 inches diameter

Here, 1 (diam.) on N or B, set to ·707 (side of square) on A,
opposite the Diameters, 6, 11, 17 on N or B are the sides of Squares nearly 4·25, 7·8, 12 on A.

Or, with the slide N or B thus set,

The sides of any squares are on A opposite the diameters of their greatest circumscribing circles on N or B.

5th.—Required the sides of squares whose areas are equal to circles 6, 8, and 9 inches diameter.

Here, 1 (diam.) on N or B set to ·886 (side of square) on A,
opposite the Diameters 6 ; 8 ; 9 ; on N or B,
are the sides 5·3; 7·09; 7·97 on A of squares whose areas very nearly correspond with the respective circles.

Or,

6th.—For the diameters of circles whose areas are equal to squares with sides 6, 8, 9 inches.

With the slide N or $\frac{B}{C}$ set as in last example,
opposite the sides 6, 8, 9 on A are the
diameters 6·76, 9·02, 10·15, on N or B for Answer.

7th.—Required the Area of Ovals 16 by 9; 17 by 11, and 19 by 13.

Here, Length × Breadth × ·7854
or, do. × do. ÷ 1·2732.

By Slide Rule,

16 on N + 9 on A + ·7854 on N; or (16 on A − 1·273 on N) + 9 on N = 1st Ans. 113 on A.

17 on N + 11 on A + ·7854 on N; or (17 on A − 1·273 on N) + 11 on N = 2nd Ans. 147 on A.

19 on N + 13 on A + ·7854 on N; or (19 on A − 1.273 on N) + 13 on N = 3rd Ans. 194 on A.

and so on for other dimensions.

POLYGONS.

The side of any regular Polygon being 1, and the number of sides from 3 to 12 inclusive, the following Table of Gauge Points gives

1st.—Diameters of least circumscribing circles.

2nd.—Areas of the Polygons.

3rd.—Diam. of Circles whose areas are equal to the Polygons.

Names.	Trigon	Square	Pentagon.	Hexagon.	Heptagon.	Octagon.	Nonagon.	Decagon.	Hardecagon.	Dodecagon.
No. of Sides.	3	4	5	6	7	8	9	10	11	12
iam. of least ircumscribing ircles	1·155	1·414	1·701	2·	2·305	2·613	2·924	3·236	3·55	3·864
Areas.	·433	1·	1·72	2·598	3·634	4·828	6·182	7·694	9·366	11·196
iam. of Circles f equal areas o Polygons ...	·7425	1·1283	1·48	1·819	2·151	2·479	2·805	3·13	3·453	3·775

And, as the diameters of least circles that will circumscribe Polygons, and the diameters of circles with equal areas to Polygons, are in direct proportion to the lengths of their respective sides; and the areas of Polygons are in proportion as the squares of their sides.

So,

1st.—Any length of side of regular Polygon in Table multiplied by the proper Gauge Point from 1st line, gives the diameter of least circumscribing circle.

2nd.—Any length of side squared, multiplied by the proper Gauge Point from 2nd line = Area of Polygon, and

3rd.—Any length of side multiplied by the proper Gauge Point from 3rd line = diameter of circle whose area is equal to the Polygon.

Or, by Slide Rule,

1st.—To find the diameter of least circle that will circumscribe any Polygon in Table,
Set 1 on N or B to the proper Gauge Point from 1st line on A, and opp. the length of side on N or B will be Answer on A.

Exs.—Required the diameters of least circles that will circumscribe regular Pentagons whose sides are 4, 5, and 6 inches in length.

In 1st place.—The proper gauge point for this example is 1·701 on the first line under Pentagon

And 1 on N or B set to 1·701 on A,
opp. 4 - do. is 6·8 on A for 1st Answer.
opp. 5 - do. is 8·5 - A - 2nd do.
opp. 6 - do. is 10·2 - A - 3rd do.

2nd.—To find the Area of regular Polygons from 3 to 12 sides. Set 1 on D to the proper Gauge Point from 2nd line on A, and opp. any length of side on D is the corresponding Answer on A.

Exs.—Required the areas of Hexagons whose respective sides are 3, 4, 5 and 7 inches.

From the Gauge Points on second line of Table, the area of Hexagon whose side is 1 = 2·598.

And 1 on D, set to 2·598 on C
opp. 3 on D is 23·4 nearly on C for 1st Answer
opp. 4 on D is 41·6 - - do. - - 2nd do.
opp. 5 on D is 65· - - do. - - 3rd do.
opp. 7 on D is 127· - - do. - - 4th do.

Or, for the Areas of regular Octagons whose respective sides are 8 and 9 inches the Gauge Point is 4·828.

And 1 on D set to 4·828 on C
opp. 8 on D is 309· nearly on C for 1st Ans.
opp. 9 on D is 391· - - do. - - 2nd do.

3rd.—To find the diameter of circles with areas equal to Polygons.

1 on N or B set to the proper Gauge Point on A
opp. any area of Polygon on N or B is the Answer on A.

Ex.—Required the diameter of circle whose area is equal to that of Hexagon with side 7 inches.

Here 1 on N or B, set to the proper Gauge Point 1·819, or say 1·82 on A,
opp. 7 on N or B, is the diameter very nearly 12·7 on A.

SUPERFICIES OF REGULAR SOLIDS.

I.—The superficies or surface of a Cube being equal to the area of one face multiplied by 6,

Length of side on D + 6 on $\frac{B}{C}$ = whole surface on A.

Ex.—Required the surface of 7 inch cube.

Here 7 on D + 6 on $\frac{B}{C}$ = 294 on A, because
7 on D is opposite its square 49 on A, and
49 on A + 6 on $\frac{B}{C}$ = Answer 294 on A.

II.—The surface of a parallelopipedon, or regular oblong piece of material, being equal to the periphery of sides multiplied by the length, plus the area of ends.

Periphery on A + length on N = Area of sides on A,
Breadth on A + twice depth on N = Area of ends, and
Sum of results = Answer.

Ex.—Required the whole surface of oblong material 17 inches long, 7 inches wide, 5 inches deep.

Here, the periphery of sides = 7 + 7 + 5 + 5 = 24 inches.
24 on A + 17 on N = 408 on A for sides surface,
And, 7 on A + 10 (5 × 2) on N giving 70 on A = area of both ends, the Answer is 408 + 70 = 478 square inches.

III.—For the whole surface of any solid cylinder.

1st.—7 (diam.) on N set to 22 (circum.) on A,
Opp. any diam. on N is its circum. on A.
2nd.—Circum. on A + length on B = convex surface on A.
3rd.—10 (diam.) on D, set to 78·54 (area) on $\frac{B}{C}$,
Opp. any diam. on D, is area on $\frac{B}{C}$ of one end.
4th.—The last result on A + 2 on N = Area of both ends on A; and
5th.—The sum of convex surface plus end areas = whole surface.

Ex.—Required the convex, and whole surface, of solid cylinder 13 ins. diameter, 37 ins. long.

1st.—7 (diam.) on N set to 22 (circum.) on A,
Opp. 13 diam. on N is its circum. on A nrly. 40·8 ins.

2nd.—40·8 (circum.) on A + 37 (length) on B = nearly 1510 on A for Convex Surface.

3rd.—10 (diam.) on D, set to 78·54 (area) on $\frac{B}{C}$,
Opp. 13 (diam.) on D, is 132·8 on $\frac{B}{C}$ for area of one end.

4th.—132·8 on A + 2 on N = 265·6 on A = areas of two ends; and

5th.—The sum of 1510 + 265·6 = 1775·6 sq. ins. whole surface.

IV.—The convex surface of CONES being equal to
Diameter of Base × $\frac{1}{2}$ Slant Side × 3·1416
Or, Radius - do. - × Slant Side - × 3·1416
And whole surface = convex surface added area of base.

1st.—Diam. on N + $\frac{1}{2}$ Slant Side on A + 3·14 on B
Or, Radius on N + Slant Side on A + 3·14 on B
= convex surface on A.

2nd.—10 (diam.) on D, set to 78·54 (area) on $\frac{B}{C}$,
Opp. any diam. on D = area on $\frac{B}{C}$,

3rd.—Whole surface = the sum of both results.

Ex.—Required the convex and whole surface of Cone whose slant height is 19 ins. and diameter of base 12.
Here, diameter being 12, or radius = 6 inches.

1st.—12 on N + 9·5 on A + 3·14 on B
Or, 6 on N + 19 on A + 3·14 on B = convex surface nearly 358 on A

2nd.—10 (diam.) on D, set to 78·5 area on $\frac{B}{C}$,
Opp. 12 diam. on D, is 113 Area of Base on $\frac{B}{C}$,
And

3rd.—358 + 113 = 471 sq. ins. whole surface or Answer.

V.—The convex surface of any sphere being equal to diameter squared multiplied by 3·1416.

Any diameter of sphere on D + 3·1416 on $\frac{B}{C}$ gives the convex surface on A.

Ex.—Required the convex surface of Globe, or Sphere, whose diameter is 16 inches.

Here, 16 on D+3·14 on $\frac{B}{C}$ = Ans. very nrly. 805 sq. ins.on A, because 16 on D is opposite its square 256 on A
and 256 on A + 3·14 on $\frac{B}{C}$ gives very nearly 805 on A.

VI.—The convex surface of segment of any sphere being equal to the circumference of whole sphere multiplied by height of segment, and the whole surface of segment equal to the last result added to the area of base; the circumference of whole sphere on A + height of segment on N = convex surface on A; and the last result added to base surface = whole surface.

Ex.—Required the convex and whole surface of segment of sphere 37 ins. diameter, when the height of segment 11 ins.

1st. 7 (diam.) on N set to 22 (circumference) on A
Opp. 37 (diam.) on N is 116 (circumference) on A,
And 116 on A+11 on B = convex surf. nrly. 1276 sq. ins. on A.

2nd. The difference between radius of sphere and height of segment being 18·5 − 11 = 7·5 inches; and
Radius of base of segment = $\sqrt{(18{\cdot}5^2 - 7{\cdot}5^2)}$

3rd. 18·5 is on D opp. its square nearly 342 on A
7·5 - - - - do. - - - do. - 56 on A,
and the difference - - - - - - 286 on A
is opp. its square root nearly - - 16·9 on D
Or, Radius of base of segment is 16·9 inches
Diameter - - do. - - 33·8 do.

4th. 10 diam. on D set to 78·54 (area) on $\frac{B}{C}$
Opp. 33·8 - do. - is nrly. 900 on $\frac{B}{C}$; and

5th. Convex surface 1276, plus area of base 900, gives whole segment surface nearly 2176 sq. ins.

The three following Tables of Gauge Points are, mainly, after the pattern of Routledge.

The figures in first Table, headed

SQUARE,

representing in column

F.F.F. the end area in square feet, for 1 foot in length
F.I.I. - do. - square inches 1 - do. -
I.I.I. - do. - - - do. - - 1 inch length.

In second Table, headed

CYLINDER,

representing in column

F.F. the end area in circular feet, for 1 foot in length
F.I. - do. - circular inches - - do. - -
I.I. - do. - - - do. - - 1 inch in length.

And in third Table, headed

GLOBE,

representing in column

F. the contents in globular feet
I. - - do. - - do. - inches

to make respectively one unit of measures, or one pound of items specified in first column.

Circular Areas of Cylinders being = Diameters squared; and
Globular Contents of Globes - = Diameters cubed.

The Gauge Points for finding the contents or weights of materials, Square, are therefore under

F.F.F. for length given in ft., side of square in ft.
F.I.I. - - do. - - ft., - - do. - - ins.
I.I.I. - - do. - - ins., - - do. - - ins.

For Cylinders, under

F.F. for length given in feet, diameter in feet
F.I. - - do. - - feet, - do. - inches
I.I. - - do. - - inches, do. - inches

And for Globes, are under

F. for Diameters given in Feet,
I. - - do. - - do. - Inches

in the respective line of measures or materials.

The Gauge Point for content in cubic feet, and weight in pounds of cast iron block 2 ft. square, 2 ft. long,

being in line Cubic Foot under F.F.F. = 1·
and in line Cast Iron - do. - do. - = ·00222,

because the dimensions are given in feet.

To find the content or weight of any material in Table of Divisors.

Arithmetically,

Side^2 × Length ÷ G. Pt. = Ans. for Square
Diam.^{2} × do. ÷ do. = do. Cylinder
Diameter^3 - - ÷ do. = do. Globe

By Slide Rule,

1st—(Length on $\frac{B}{C}$ — G. Pt. on A) + side of square on D.
Or,
Length on $\frac{B}{C}$, set to the proper G. Pt. on A,
Opposite the side of Square - - - on D,
Is the content, or weight - - - - on $\frac{B}{C}$, for Square.

2nd—(Length on $\frac{B}{C}$ — G. Pt. on A + Diam. of Cylinder on D
Or,
Length on $\frac{B}{C}$, set to the proper G. Pt. on A,
Opposite the Diameter of Cylinder on D,
Is the content, or weight - - - on $\frac{B}{C}$, for Cylinder.

3rd—(Diameter on $\frac{B}{C}$ — G. Pt. on A) + Diam. of Globe on D.
Or,
Diam. of Globe on $\frac{B}{C}$, set to proper G. Pt. on A,
Opposite the Diameter of Globe - - on D,
Is the content, or weight - - - - on $\frac{B}{C}$, for Globe.

SQUARE — DIVISORS.

Names.	F.F.F.	F.I.I.	I.I.I.
Cubic Inch	·000579	·0833	1·
Cubic Foot	1·	144·	1728·
Imperial Gallon ...	·1603	23·1	277·123
Air, 32° Fahr.	12·4	1784·	21405·
Water, 62° Fahr. ...	·016	2·31	27·7
Mercury	·00118	·17	2·04
Lead	·00140	·202	2·43
Copper, hammered ...	·0018	·259	3·11
„ sheet	·00182	·262	3·15
„ cast	·00186	·268	3·22
Bronze	·00191	·275	3·3
Brass	·00198	·286	3·43
Steel	·00204	·294	3·53
Wrought Iron	·00208	·3	3·6
Tin	·00216	·312	3·74
Cast Iron	·00222	·32	3·84
Zinc	·00229	·33	3·96
Sandstone	·00694	1·	12·
Masonry	·0077	1·108	13·3
Brickwork	·0089	1·28	15·4
Sand, dry	·0112	1·62	19·4
Coals, heaped	·0208	3·	36·
Yellow Pine, dry ...	·0345	4·97	59·6
Beech „ ...	·0233	3·35	40·2
Birch „ ...	·0225	3·24	38·9
Ash „ ...	·0213	3·07	36·8
Oak, av. „ ...	·0192	2·77	33·2
Box „ ...	·0167	2·4	28·8
Teak, African „ ...	·0164	2·36	28·3

APPLICATION OF TABLE: SQUARE—DIVISORS.

Ex. 1st.—Required the cubic inches, cubic feet, and imperial gallons in cistern 1·5 ft. square, 6 ft. deep; also the weight in pounds of a cast iron block the same dimensions.

All the dimensions in this Example being feet, the Gauge Points are

In line cubic inch under F.F.F. = ·000579
- do. cubic foot - - do. = 1·
- do. impl. gallon - - do. = ·1603
- do. cast iron - - - do. = ·00222

And

1st—6 (length) on $\frac{B}{C}$ set to ·000579 on A
opp. 1·5 (ft. sq.) on D is nrly. 23300 cub. ins. on $\frac{B}{C}$

2nd—6 (length) - on $\frac{B}{C}$ set to 1· - - - on A
opp. 1·5 (ft. sq.) on D is 13·5 cub. ft. on $\frac{B}{C}$

3rd—6 (length) on $\frac{B}{C}$ set to - ·1603 - on A
opp. 1·5 (ft. sq.) on D is nrly. 84· impl. galls. on $\frac{B}{C}$

And

4th—6 (length) on $\frac{B}{C}$ set to - - ·00222 - on A
opp. 1·5 (ft. sq.) on D is nrly. 6080· pds. cast iron on $\frac{B}{C}$

Ex. 2nd.—Required the cubic feet, and the weight in pounds of wrought iron block 9 inches square, 2 ft. long.

The dimensions in this example being given for side of square inches, and length in feet,

G. Pt. is in line Cub. Ft. under F.I.I. = 144
Do. - - do. Wrt. Iron do. do. = ·3

And

2 (length) on $\frac{B}{C}$ set to 144 - - - - on A
opp. 9 (Ins. sq.) on D is 1·125 Cub. Ft. on $\frac{B}{C}$

And 2 (length) on $\frac{B}{C}$ set to ·3 - - - - - on A
opp. 9 (Ins. sq.) on D is Ans. 540 pds. Wrt. Iron on $\frac{B}{C}$

CYLINDER—DIVISORS.

Names.	F.F.	F.I.	I.I.
Cubic Inch	·000737	·106	1·2732
Cubic Foot	1·2732	183·3	2200·
Imperial Gallon ...	·204	29·4	352·8
Air, 32° Fahr.	15·77	2271·	27253·
Water, 62° Fahr. ...	·0204	2·94	35·28
Mercury	·0015	·216	2·59
Lead	·00179	·257	3·09
Copper, hammered ...	·00229	·33	3·96
„ sheet	·00232	·333	4·
„ cast	·00237	·341	4·1
Bronze	·00243	·35	4·2
Brass...	·00253	·364	4·37
Steel	·0026	·374	4·49
Wrought Iron	·00265	·382	4·58
Tin	·00276	·397	4·76
Cast Iron	·00283	·407	4·89
Zinc	·00292	·42	5·04
Sandstone...	·00884	1·273	15·28
Masonry	·0098	1·412	16·94
Brickwork...	·0114	1·64	19·6
Sand, dry	·0143	2·06	24·7
Coals, heaped	·0265	3·82	45·84
Yellow Pine, dry ...	·0439	6·32	75·8
Beech „ ...	·0296	4·26	51·2
Birch „ ...	·0286	4·12	49·5
Ash „ ...	·0271	3·9	46·8
Oak „ ...	·0245	3·53	42·3
Box „ ...	·0212	3·05	36·6
African Teak „ ...	·0208	3·	36·

APPLICATION OF CYLINDER DIVISORS.

Ex. 1st.—Required the cubic inches, cubic feet, and imperial gallons in 32 inches diameter, 6 feet long; also the weight in pounds of cast iron block same dimensions.

In this example the length being given in feet, and diameter in inches; the Gauge Points are

On line Cubic Inch - under F.I. = ·106
do. - Cubic Foot - - do. - = 183·3
do. - Imperial Gallon - do. - = 29·4
do. - Cast Iron - - - do. - = ·407

And

(6 on $\frac{B}{C}$ — ·106 on A) + 32 on D = Cub. Ins. on $\frac{B}{C}$
(6 do. — 183·3 do.) + 32 do. = Cub. Ft. do.
(6 do. — 29·4 do.) + 32 do. = Gallons - do.
(6 do. — ·407 do.) + 32 do. = Pounds - do.

Or,

1st—Length 6 on $\frac{B}{C}$ set to - - ·106 - - - - - on A,
opp. 32 on D is nrly. 58000 Cub. Ins. - - on $\frac{B}{C}$.

2nd—Length 6 on $\frac{B}{C}$ set to 183·3 - - - - - - on A,
opp. 32 on D is nrly. 33·5 Cub. Ft. - - - on $\frac{B}{C}$.

3rd—Length 6 on $\frac{B}{C}$ set to 29·4 - - - - - - on A,
opp. 32 on D is nrly. 209 Gallons - - - on $\frac{B}{C}$.

4th—Length 6 on $\frac{B}{C}$ set to ·407 - - - - - on A,
opp. 32 on D is nrly. 15100 Pounds - on $\frac{B}{C}$.

Ex. 2nd.—Required the weight of 4 ins. diam., 9 ins. long. wrought iron

Length 9 on $\frac{B}{C}$ set to its G. Pt. 4·58 - - on A
opp. Diam. 4 on D is Ans. nrly. 31·5 Pounds on $\frac{B}{C}$.

GLOBE—DIVISORS.

Names.	F.	I.
Cubic Inch	·001105	1·91
Cubic Foot	1·91	3300·
Imperial Gallon ...	·306	529·
Air, 32° Fahr.	23·65	40880·
Water 62° Fahr. ...	·0306	52·9
Mercury	·00225	3·89
Lead	·00268	4·63
Copper, hammered ...	·00343	5·93
„ sheet	·00348	6·02
„ cast	·00356	6·15
Bronze	·00365	6·3
Brass	·00379	6·54
Steel	·00390	6·75
Wrought Iron	·00398	6·88
Tin	·00413	7·14
Cast Iron	·00424	7·33
Zinc	·00438	7·57
Sandstone	·0133	22·9
Masonry	·0147	25·4
Brickwork...	·0170	29·5
Sand, dry	·0214	37·
Yellow Pine, dry ...	·066	114·
Beech „ ...	·0444	76·8
Birch „ ...	·0431	74·5
Ash „ ...	·0406	70·2
Oak „ ...	·0367	63·5
Box „ ...	·0318	55·
African Teak „ ...	·0313	54·1

APPLICATION OF GLOBE DIVISORS.

Exs. 1st.—Required the cubic inches and pounds in cast iron Globes 6, 8, and 9 ins. diameter.

The diameters being Inches, the Gauge Points are

On line Cubic Inch under I. = 1·91
do. Cast Iron - do. - = 7·33

And

1st.—Diam. 6 on $\frac{B}{C}$ - - set to 1·91 - - - - on A
Do. 6 on D is opp. nrly. 113 Cub. Ins. - on $\frac{B}{C}$

2nd.—Diam. 8 on $\frac{B}{C}$ - - set to 1·91 - - - - on A
Do. 8 on D is opp. nrly. 268 Cub. Ins. - on $\frac{B}{C}$

3rd.—Diam. 9 on $\frac{B}{C}$ - - set to 1·91 - - - - on A
Do. 9 on D is opp. nrly. 382 Cub. Ins. - on $\frac{B}{C}$

Or,

1st.—Diam. 6 on $\frac{B}{C}$ - - set to 7·33 - - - - on A
Do. 6 on D is opp. nrly. 29·5 Pds. Cast Iron on $\frac{B}{C}$

2nd.—Diam. 8 on $\frac{B}{C}$ - - set to 7·33 - - - - on A
Do. 8 on D is opp. nrly. 70· Pounds - - on $\frac{B}{C}$

3rd.—Diam. 9 on $\frac{B}{C}$ - - set to 7·33 - - - - on A
Do. 9 on D is opp. nrly. 99·5 Pounds - - on $\frac{B}{C}$
for the respective Answers.

Exs. 2nd.—Required the weight of 8 inch Brass Globe.

On line Brass, Gauge Point is under I = 6·54

And,

Diam. 8 on $\frac{B}{C}$ - - - - set to 6·54 - - on A
Do. 8 on D is opp. Ans. nrly. 78·5 Pounds on $\frac{B}{C}$

APPLICATION OF TABLE, MULTIPLIERS.

But, contents and weights of square, circular and globular materials, are obtainable in many instances most readily and confidently, by using Multipliers instead of Divisors, as shown in the following examples illustrating the application of improved Slide Rule to the Table on next page.

Ex. 1st.—Required the content, in Imperial Gallons, of working barrel 9 inches diameter, 6 feet long.

From Table of Multipliers

A cylinder 1 foot, or 12 inches diameter, 1 foot long, contains 4·897, say 4·9 gallons.

Therefore,

1st.—Diam. 12 on D set to 4·9 galls. on $\frac{B}{C}$
opp. Do. 9 on D is nrly. 2·75 galls. on $\frac{B}{C}$ for 1 foot long.

2nd.—Length 1 (ft.) on N or B, set to 2·75 galls. on A
opp. Do, 6 (ft.) on N or B, is Ans. 16·5 galls. on A

Ex. 2nd.—Required the content in cubic inches, and the weight in pounds, of 6 inch square bar of wrought iron, 1 foot long.

From Table,

1 ft. square, 1 ft. long = 1728 cubic inches
- Do. - - - do. - = 480 pounds wrt. iron.

Therefore,

1st.—12 (sq. in.) on D set to 1728 cub. ins. on $\frac{B}{C}$
opp. 6 - do. - do. is Ans. 432 - do. - do.

2nd.—12 (sq. in.) on D set to 480 pounds on $\frac{B}{C}$
opp. 6 - do. - do. is Ans. 120 - do. - do.

MULTIPLIERS.

Measures and Materials.	Square. 1 Ft square 1 Ft. long.	Cylinder. 1 Ft. diam. 1 Ft. long.	Globe. 10 Ins. Diam.
Cubic Inches	1728	1357	523·6
Cubic Feet	1	·7854	·303
Imperial Gallons ...	6·236	4·897	·189
Air ... ... Pds.	·0807	·0634	·0244
Water ... ... „	62·36	49	18·9
Mercury ... ... „	848	666	257
Lead ... ... „	712	559	216
Copper, hammered „	556	437	168
„ sheet ... „	549	431	166
„ cast ... „	537	422	163
Bronze ... ... „	524	412	159
Brass ... ... „	504	396	153
Steel ... ... „	490	385	148
Wrought Iron ... „	480	377	145
Tin ... ... „	462	363	140
Cast Iron ... ... „	450	353	137
Zinc ... ... „	436	342	132
Sandstone ... ... „	144	113	43·6
Masonry ... ... „	130	102	39·4
Brickwork ... ... „	112	88	33·9
Sand, dry ... ... „	89	70	27
Coals, heaped ... „	48	37·7	14·5
Yellow Pine, dry „	29	22·8	8·8
Beech „ „	43	33·8	13
Birch „ „	44·4	34·8	13·5
Ash „ „	47	36·9	14·2
Oak „ „	52	40·8	15·7
Box „ „	60	47·1	18·2
African Teak „ „	61	47·9	18·5

Exs. 6th.—Required the weight of cast iron shells, whose external diameters are 7; 8; 9 ; and 10 inches, and internal - do. - - 5; 6; 6·5; and 7·5 do.

In 1st place—The Gauge Point for Globes in these examples being on line Cast Iron, under 10 inch = 137 pounds,
10 (diam.) on Cube Root line, set to
137 (pds.) on the 3rd radius of N,

Opposite 7 (diam.) on Cube Root line is 47 pounds on N,
do. 5 (diam.) - do. - - 17 do. - do.
Weight of 7 inch shell = 30 pounds.

Opposite 8 (diam.) on Cube Root line is 70 pounds on N.
do. - 6 (diam.) - do. - - 29·5 do. - do.
Weight of 8 inch shell = 40·5 pounds.

Opposite 9 (diam.) on Cube Root line is 99·5 pounds on N,
do. - 6·5 (diam.) - do. - - 37·5 do. - do.
Weight of 9 inch shell = 62 pounds.

Opposite 10 (diam.) on Cube Root line is 137 pounds on N,
do. - 7·5 (diam.) - do. - - 57·8 do. - do.
And weight of 10 inch shell = 79·2 pounds.

Ex. 7th.—Required the thickness of sheet copper for globular float 8 ins. external diameter, half immersed in water.

In 1st place - - 10 in. globe of water = 18·9 pds.
- do. - - - 10 in. do. copper = 166 do.

2nd—10 (diam.) on Cube Root line set to 18·9 lbs. water
Or, 10 do. - - do. - - do. - 166 lbs. copper
Opp. 8 do. - - do. - - - - - is 9·65 lbs. water
8 do. - - do. - - - - - is 85 lbs. copper

3rd—Half the weight of 8 in. globe of water being 4·82 lbs.; 85 − 4·82 gives 80·18 lbs. as the weight of copper that would be required to fill the cavity of float.

4th.—80·18 on slide N set for sheet copper being opposite 7·85 ins. on Cube Root line = internal diam. of float.

5th— $\frac{8-7{\cdot}85}{2} = \frac{{\cdot}15}{2}$ = Ans. ·075 ins. thick.

MISCELLANEOUS EXAMPLES

Illustrating the use of improved Slide Rule in various calculations.

MECHANICAL POWERS.

Any machine, simple or compound, which enables any force or power to lift greater weight, or overcome greater resistance than itself, in the same time, is called a mechanical, or combination of mechanical powers; and the advantage gained by such machine is always in the same proportion as the space moved by the power is to that moved by the weight, when both reduced to vertical motion.

Thus, a machine whereby the power moves 6 feet, while the weight or resistance moves only 1 foot, gives an advantage 6 to 1; 100 pounds power being sufficient to overcome 600 pounds resistance. Or, in the commonly expressed terms,

Power can only be gained at the expense of Speed, and Speed at the expense of Power; whatever mechanical power is applied.

Of the simple Mechanical Powers, Lever, Wheel and Axle, Pulley, Inclined Plane, Wedge, and Screw; the Lever and Inclined Plane may be said to include the whole six; Wheel and Axle forming lever of first order, the movable Pulley, lever of second order, and the Wedge, and Screw, modifications of the Inclined Plane.

LEVER.

Of the three orders of Levers, the
1st has fulcrum between power and weight
2nd has weight between power and fulcrum; and
3rd has power between weight and fulcrum
The fulcrum being taken as centre of motion

And, calling the distance from
Fulcrum to Weight = Weight Arm, and from
- Do. - Power = Power Arm.

1st—The Weight Arm × Weight ÷ Power Arm = Power.
2nd—The Weight Arm × Weight ÷ Power = Power Arm.
3rd—The Power Arm × Power ÷ Weight Arm = Weight.
4th—The Power Arm × Power ÷ Weight = Weight Arm.

By Slide Rule,

1st—The Power Arm on N or B, set to Weight Arm on A
opp. the Weight - - N or B, is the Power - - on A

2nd—The Power - on N or B, set to Weight Arm on A
opp. the Weight - on N or B, is the Power Arm on A

3rd—The Weight Arm on N or B, set to Power Arm on A
opp. the Power - - on N or B, is the Weight - on A

4th—The Weight - on N or B, set to Power Arm on A
opp. the Power - - on N or B, is the Weight Arm on A

Ex. 1st.—Suppose a Lever of "1st order" 60 inches long, Fulcrum 6 inches from one end; Weight to be lifted 450 pounds. Required the Power to be exerted.

Here, 60 ins. − 6 inches Weight Arm = 54 ins. Power Arm

And
54 on - N or B, set to - - 6 - - on A
opp. 450 (pds.) on N or B, is the Power 50 pounds on A=Ans.

WHEEL AND AXLE.

1st.—To find the mechanical advantage gained by this arrangement, excluding friction,

Divide the diameter of wheel, or circle, to which the power is applied, by the diameter of axle, and the quotient will give proportionate advantage to 1.

Ex. 1st.—Wheel 24 ins. ÷ Axle 4 ins. = 6 to 1 advantage.

Ex. 2nd.—In double-geared hand-crane, the

Radius of Winch = 16·5 ins. = 33 in. diam. of Winch circle
Diameter of 1st Pinion 4 ins.; 1st Wheel, 30 ins.
- do. - 2nd - do. - 6 ins.; 2nd do. 36 ins.
- do. - Barrel at centre of coil - - - 8 ins.; and the
Force, or power, applied to Winch - - - 56 pounds;

required the stress on cogs of wheels, and on rope, or chain,

By Slide Rule,

1st.— (33 on A − 4 on N) + 56 on N = 455 pounds on A for stress on cogs of 1st Wheel

2nd.—(30 on A − 6 on B) + 455 on B = 2275 pounds on A for stress on cogs of 2nd Wheel.

3rd.—(36 on A − 8 on N) + 2275 on N = nrly. 10240 pounds on A for stress on rope, or chain.

Or,

1st.— 4 on N set to 33 on A
Opp. 56 do. is 455 lbs. on A = stress on 1st Wheel.

2nd.— 6 on B set to 30 on A
Opp. 455 do. is 2275 lbs. on A = stress on 2nd Wheel.

3rd.— 8 on N set to 36 on A
Opp. 2275 do. is nrly. 10240 lbs. on A = stress on rope or chain

PULLEY.

The advantage gained by this mechanical power in common blocks, being in the same proportion, as the number of rope or chain connections between fixed and movable block is to 1, when no friction.

Arithmetically,

Power × No. of connections = Weight; and
Weight ÷ - - do. - - = Power

Or, by Slide Rule,

Power on A + No. of connections on N or B = Weight on A,
And,
Weight on A — - - do. - - - do. = Power on A.

Or, Unity on N or B, set to Power on A
Opp. No. of connections on N or B
Is Weight - - - - - - - on A
Or,
No. of connections - on N or B
Set to Weight - - - - - on A
Opp. Unity - - - - on N or B
Is Power - - - - - - - on A

Ex. 1st.—A Power of 70 pounds is required to lift a given weight with pair of three-sheaved blocks. What number of pounds will represent the weight, supposing friction nothing?

In this example, the movable block being attached to fixed block by six connections of rope, or chain,

70 (lbs.) on A + 6 on N or B = 420 lbs. on A = Weight.

Or, 1 (Unity) on N or B, set to 70 lbs. Power on A,
Opp. 6 connections on N or B is 420 lbs. Weight on A as before.

INCLINED PLANE.

To find the Power required to counterbalance weight on any inclined plane, supposing Power applied in direction parallel to plane, and friction not reckoned.

Arithmetically,

As Height of Plane : Length :: Power : Weight.
„ Length of do. : Height :: Weight : Power.
„ Power - - - : Weight :: Height : Length.
„ Weight - - - : Power :: Length : Height.

Or, For any of the above statements

By Slide Rule,

1st Term on N or B set to 2nd Term on A
Opp. 3rd do. - do. - is 4th do. do.

Or, (2nd, or 3rd Term, on A − 1st Term on N or B) + remaining Term on N or B = 4th Term on A.

Ex.—Suppose length of inclined plane 36 ft., height 4 feet, power in direction of plane 9 lbs., and weight 81 lbs. Required the Answer by Slide Rule, when any three of the terms given to find the fourth.

1st.— 4 on N or B, set to 36 on A
Opp. 9 on do. - is 81 lbs. Weight on A.

2nd.—36 on N or B, set to 4 on A
Opp. 81 on do. - is 9 lbs. Power on A.

3rd.— 9 on N or B, set to 81 on A
Opp. 4 on do. - is 36 ft. Length on A; and

4th.— 81 on N or B, set to 9 on A
Opp. 36 on do. - is 4 ft. Height on A.

SCREW.

Calculating this power without reckoning resistance from friction, the circumference of circle described by the force applied, being called Power Circle; and the distance between centres of two contiguous coils of thread, the Pitch,

Arithmetically,

As Pitch	:	Power Circ.	::	Power	:	Weight
„ Power Circ.	:	Pitch	::	Weight	:	Power
„ Power	:	Weight	::	Pitch	:	Power Circ.
„ Weight	:	Power	::	Power Circ.	:	Pitch

Or, by Slide Rule,

1st Term on N or B set to 2nd Term on A,
Opp. 3rd do. - do. - is 4th do. - do.

Ex.—The thread of screw - - - = ½ in. Pitch.
- Power circle - - - - = 75 Inches.
- Force applied - - - = 30 Pounds.
- Weight - - - - - = 4500 Pounds.

Required the 4th Term in any preceding statements, supposing the other three terms given.

1st.—To find the Weight
(75 on A − ·5 on N or B) + 30 on N or B = Ans. 4500 lbs. on A

2nd.—To find the Power
(·5 on A − 75 on N or B) + 4500 on N or B = Ans. 30 lbs. on A

3rd.—To find the Power Circle
(4500 on A − 30 on N or B) + ·5 on N or B = Ans. 75 ins. on A

4th.—To find the Pitch.
(30 on A − 4500 on N or B) + 75 on N or B = Ans. ½ in. on A.

Table of cohesive strengths, derived from Kirkaldy's Experiments in Wrought Iron and Steel, and Barlow's Treatise on the strength of Timber.

Remarks.	Expts.	Max.	Min.	Av.
		CAST STEEL.		
		Pds.	Pds.	Pds.
Bars	38	148,294	84,036	116,254
Plates L	17	95,360	67,977	82,154
Do. C	13	99,952	67,538	85,798
		PUDDLED STEEL.		
Bars	22	75,304	42,564	67,841
Plates L	8	108,906	65,045	92,688
Do. C	6	99,468	63,098	81,211
		WROUGHT IRON—YORKSHIRE.		
Bars	32	67,876	58,228	61,953
Plates L	17	61,184	47,426	54,156
Do. C	20	60,756	40,541	49,712
		WROUGHT IRON—MISCELLANEOUS.		
Bars	131	68,848	47,095	59,047
Plates L	146	60,985	41,002	50,217
Do. C	138	55,697	32,450	45,377
		TIMBER—DRY.		
Box	3		about	20,000
Ash	6			17,000
Teak	3			15,000
Fir	12			12,000
Beech	3			11,500
Oak	6			10,000
Pear	3			9,800
Mahogany	3			8,000

The lines marked L, in Table last page, refer to plates rolled in same direction as test, those marked C, to plates rolled crossways of test; and the figures in table being absolute weights to tear asunder one inch square of the materials named, the practice of engineers is to take factors of safety

from - $\frac{1}{3}$ - to - $\frac{1}{6}$ - for Wrought Iron, and
from - $\frac{1}{5}$ - to - $\frac{1}{10}$ - for Timber.

Ex. 1.—Required the working stress for $1\frac{1}{2}$ inch square bar of cast steel, supposing the ultimate strength of material 84000 pounds per square inch, and factor of safety $\frac{1}{6}$, or 14000 lbs.

Here, Arithmetically,

$1{\cdot}5^2 = 2{\cdot}25$, and $14000 \times 2{\cdot}25 = 31500$ lbs. Answer.

Or, by Slide Rule,

1 on D set to 14000 lbs. on $\frac{B}{C}$
Opp. 1·5 on D is 2·25 on A, and Ans. 31500 lbs. on $\frac{B}{C}$

Ex. 2nd.—Required the working stress for wrought iron bar $1\frac{1}{4}$ inch diameter, supposing the ultimate breaking weight of material = 50000 pounds per sq. inch, and factor of safety $\frac{1}{5}$ = 10000 pounds.

Here 1 (diam.) on D set to ·7854 (Area of 1) on $\frac{B}{C}$
Opp. 1·25 (diam.) - do. is 1·227 - (Area) on $\frac{B}{C}$

Or, 1 (sq. in.) on N or B, set to 10000 pounds on A,
Opp. 1·227 do. - do. - - is 12270 do. do. = Ans.

And 1 (sq. in.) on N or B, set to ·7854 area on A
Opp. any stress per sq. inch on N or B
is the corresponding stress per circular inch on A.

CHAINS.

Glynn, in his "Rudimentary Treatise on the construction of Cranes," remarks,

"Taking chains made of iron inch diameter as the standard; crane chain, with short links, may be proved to 14 tons, and worked safely to half the strain to which they have been proved, but not to more."

And as the weight per fathom of short linked chain made from iron inch diameter is 56 pounds, and the weight and proof strain of chains may be estimated in proportion to the squares of the iron's diameter of which they are made.

1 inch = 16 sixteenths; 14 tons = 280 cwt.

And, by Slide Rule,

16 (sixteenths) on D, set to weight 56 lbs. on $\frac{B}{C}$
Or, 16 - do. - - do. - do. proof 280 cwts. do.

Opposite any other dimension in sixteenths of an inch on D is answer on $\frac{B}{C}$ for chains from $\frac{1}{2}$ to 1 inch inclusive.

EXAMPLES.

Required the weight per fathom, and the proof strain in cwts., of

$\frac{1}{2}$ inch; $\frac{3}{4}$ inch; and $\frac{7}{8}$ inch chains.

Here $\frac{1}{2}$ inch = $\frac{8}{16}$; $\frac{3}{4}$ = $\frac{12}{16}$; $\frac{7}{8}$ = $\frac{14}{16}$. And

16 (sixteenths) on D - set to - 56 lbs. on $\frac{B}{C}$
Or, 16 - do. - do. - do. - 280 cwt. do.
Opp. 8 - do. - do. - is weight 14 lbs. on $\frac{B}{C}$ } = $\frac{1}{2}$ in.
„ „ - do. - do. - is proof 70 cwt. do. }
„ 12 - do. - do. - is weight 31·5 lbs. do. } = $\frac{3}{4}$ in.
„ „ - do. - do. - is proof 157·5 cwt. do. }
„ 14 - do. - do. - is weight 43 lbs. do. } = $\frac{7}{8}$ in.
„ „ - do. - do. - is proof 215 cwt. do. }

WHITWORTH THREADS.

A screw bolt on Whitworth's system has its diameter at bottom of thread equal to

Diam. of bolt − (Pitch × 1·28), as shown in following

TABLE.

Diam. of Bolt.	Diameter at Bott. of Thread.	Threads per Inch.	Pitch of Thread.
½ in.	·393	12	·0833
⅝	·509	11	·0909
¾	·622	10	·1
⅞	·733	9	·1111
1	·84	8	·125
1⅛	·942	7	·143
1¼	1·067	7	·143
1⅜	1·162	6	·167
1½	1·287	6	·167
1⅝	1·369	5	·2
1¾	1·494	5	·2
1⅞	1·591	4½	·222
2	1·716	4½	·222
2¼	1·93	4	·25
2½	2·18	4	·25
2¾	2·383	3½	·286
3	2·633	3½	·286
3¼	2·856	3¼	·308
3½	3·106	3¼	·308
3¾	3·323	3	·333
4	3·573	3	·333

Ex. 1.—Suppose a Whitworth screw bolt 1¼ in. diameter, has to carry 5000 pounds; what is the stress per square inch of section at bottom of thread?

From Table last page,

1¼ inch bolt is 1·067 in. diam. at bottom of thread

And

1 (diam.) on D set to ·7854 (area) on $\frac{B}{C}$

Opp. 1·067 do. - on D is nrly. ·89 area on $\frac{B}{C}$

And

·89 (area) on N or B set to 5000 (lbs.) on A

Opp. 1·067 do. on N or B is nrly. 5600 lbs. on A

for stress per square inch.

Ex. 2.—A Whitworth screw bolt has to carry 8000 pounds, and maximum stress not exceed 7000 pounds per circular inch; required the size of bolt.

Here, 7000 (pounds) on $\frac{B}{C}$ set to 1 (diam.) on D

Opp. 8000 - do. - - do. is 1·07 (diam.) on D, for diameter at bottom of thread; and which is seen in Table to correspond very nearly with 1¼ inch bolt.

Ex. 3.—A Whitworth screw bolt is to be loaded with 7000 lbs. per sq. inch; required the diameter to carry 8000 pounds.

Here 7000 on N or B set to 1 sq. in. on A

Opp. 8000 on do. is 1·143 do. on A

And

·7854 Area on $\frac{B}{C}$ set to 1 (diam.) on D

Opp. 1·143 - do. - is nrly. 1·22 do. on D,

or rather less than the diameter at bottom of thread of 1¼ in. bolt.

TRANSVERSE STRENGTH OF MATERIALS.

Taking the authorities, "Barlow's Treatise on the Strength of Timber," "Fairbairn on the Application of Cast and Wrought Iron to Building Purposes," and the Blue Book "Report of the Commissioners appointed to enquire into the Application of Iron to Railway Structures," the transverse strength of sundry bars of Timber, Wrought Iron, and Cast Iron, are shown on next page; and for Timber, and Cast Iron, Bars reduced to inch square, 1 foot between supports, the breaking weights, and loads for factors of safety $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, are as follow:

Materials.	Breaking Weights.			Safety Factors.		
	Max.	Min.	Av.	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$
Timber.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Teak	892	717	805	268	201	161
Ash	682	665	673	224	168	135
Oak, Canada	619	570	594	198	148	119
„ Dantzic	507	455	481	160	120	96
„ English	568	545	556	185	139	112
Pine, Pitch...	568	520	544	181	136	109
„ Red ...	464	414	439	113	110	88
Beech	538	494	516	172	129	103
Larch	414	312	363	121	91	73
Cast Iron.						
Cold Blast ...	2551	1813	2182	727	545	436
Hot do. ...	2443	1588	2015	672	504	403

The breaking weights and safe loads for other bars being $= \frac{\text{Breadth} \times \text{Depth}^2 \times \text{Constant}}{\text{Length}}$, when length in feet, and breadth and depth in inches.

	HT AND DEFLECTION.		AUTHORITY.
	Av.	Deflec.	
	Pounds.	Inches.	
Teak	... 938...	... 4·32...	...Barlow ...
Ash...	... 772...	... 8·92...	... Do. ...
Oak, C	... 673...	... 6· ...	... Do. ...
... D	... 560...	... 4·86...	... Do. ...
... E	... 637...	... 8·1 ...	... Do. ...
Pine, P	... 622...	... 6· ...	... Do. ...
... R	... 511...	... 5·83...	... Do. ...
Beech	... 593...	... 5·73...	... Do. ...
Larch	... 501...	... 5· ...	... Do. ...
WROUGH	... ...	... .	... Do. ...
... D	... ...	... ...	... Do. ...
... D	... ...	... .	... Do. ...
C			
Cold Bl	... 452...	... 1·675	...Fairbairn...
Hot d	... 443...	... 1·5 ...	... Do. ...
Clyde I	...2113...	... ·73...	...Blue Book
... Do.	...2234...	... ·4 ...	... Do. ...
... Do.	...4383...	... ·46...	... Do. ...
... Do.	...3084...	... ·36...	... Do. ...
... Do.	...1842...	... 3·09...	... Do. ...
... Do.	...4033 ..	... 2·08...	... Do. ...

Ex.—Required the breaking weight of hot blast cast iron beam 7 ft. between supports, 2 ins. broad, 5 ins. deep, loaded in middle; reckoning constant 2015 pounds average.

By Slide Rule,

' Any depth on D being opposite its square on A

The

(Square on A – Length on N) + Breadth on N + Constant on B gives Answer on A.

Or, 5 on D being opposite its square 25 on A;

(25 on A – 7 on N) + 2 on N + 2015 on B = Ans. nrly. 14400 lbs. on A.

For relative strengths,

Beam supported at ends, loaded in middle, being	1	or	4
Do. - - do. - - loaded uniformly - is	2	or	8
Do. fixed at ends, loaded in middle - - - is	1·5	or	6
Do. - do. - loaded uniformly - - - is	3	or	12
Do. fixed at one end, loaded at other - - is	·25	or	1
Do. - - do. - - loaded uniformly - - is	·5	or	2

A beam not loaded in middle, will carry weight in proportion to that it will carry in middle, as

Product of long end multiplied by short end, is to the square of half distance between supports,

And,

Product of long end multiplied by short end, divided by quarter distance between supports, gives the effective length, or distance between supports of same beam, loaded in middle, to give equal strength

A Beam 8·4 ft. between supports, loaded in middle, being same strength as beam 10 ft. between supports, loaded 3 ft. from one end.

Ex.—Required the load applied 3 ft. from one end of beam 10 feet between supports, to give same stress as 42 cwt. in middle.

Here $10 \div 2 = 5$ ft. for half distance between supports.
$10 - 3 = 7$ ft. for long end of beam.
$7 \times 3 = 21$ for product of long × short end.

And

$$\text{As } 21 : 5^2 :: 42 \text{ cwt.} : \text{Ans.}$$

By Slide Rule. 5 on D is opp. its square 25 on A
(25 on A − 21 on N or B) + 42 on N or B = Ans. 50 cwts. on A.

And $10 \div 4$ giving 2·5 ft. for $\frac{1}{4}$ distance between supports.
$21 \div 2{\cdot}5$ gives 8·4 ft. effective length between supports of same beam, to carry 50 cwt. in middle.

Again—The formula,

$$\frac{\text{Area of bottom flange} \times \text{depth} \times \text{constant}}{\text{Length}} = \text{breaking weight}$$

in Tons of Hodgkinson's Cast Iron Girder, with constant 26,
and of Fairbairn's Wrought Iron do. - - do. 60,
all the dimensions being in inches.

Or, by Slide Rule,
(Area of bott. flange on A − length on N) + depth on N + constant on B = breaking weight in tons on A.

Or, Length - on N set to area of bottom flange on A
Opp. Depth - on N is Product - - - - on A;
And 1 - - on B set to last Product - - - on A
Opp. Constant on B is Answer - - - - on A

Or, to apply the Slide Rule to examples given on pages 27 and 105 of Fairbairn's "Application of Cast and Wrought Iron to Building Purposes."

Ex. 1.—Required the breaking weight of cast iron beam, loaded in middle, Hodgkinson's section.

Distance between supports 26 feet -	= 312	inches.
Depth of beam in middle - - - - -	27·5	do.
Area of bottom rib section = (16 × 3) =	48	do.

Here (48 on A − 312 on N) + 27·5 on N + 26 constant on B = 110 tons breaking weight on A = Answer.

Ex. 2.—Required the breaking weight of wrought iron girder (Fairbairn's), when

Distance between supports 24 feet -	288	inches.
Depth in middle - - - - - - - -	16	do.
Area of bottom rib - - - - - - -	7	do.

Here, (7 on A − 288 on N) + 16 on N + 60 constant on B = Ans. 23·3 tons on A, for ultimate strength of wrought iron girder.

CAST IRON PILLARS.

To apply the improved Slide Rule in calculating strengths of solid pillars of cast iron, by Hodgkinson's latest formula.

$$\frac{\text{Diameter}^{3\cdot5}}{\text{Length}^{1\cdot63}} \times 42{\cdot}347 = \text{Brkg. weight in tons.}$$

And of hollow pillars,

$$\frac{\text{Ext. diam.}^{3\cdot5} - \text{Int. diam.}^{3\cdot5}}{\text{Length}^{1\cdot63}} \times 42{\cdot}347 = \text{Breaking weight.}$$

The length of pillar being not less than thirty diameters;
- length in feet; the diameter in inches;
- ends of pillars flat and well bedded;

and 42·347 Tons the breaking weight of solid cast iron pillars 1 inch diameter, 1 foot long.

Ex.—Required the breaking weight of solid cast iron pillar $2\frac{1}{2}$ inches diameter, 10 ft. long, whose ends are flat-faced and well bedded.

From No. 2 Face of improved Slide Rule

Common Logarithm of 2·5 (diam.) = 0·398
Do. - - do. of 10 (length) = 1·

Log. 0·398 on A + 3.5 on N or B = Log. 1·393 on A
„ 1· on A + 1·63 - do. = Log. 1·63 on A

1·393 is Common Log. of 24·7
1·63 - do. - do. - 42·7

3·5 power of 2·5 = 24·7
1·63 - do. 10· = 42·7

The Formula $\frac{2{\cdot}5^{3{\cdot}5}}{10^{1{\cdot}63}} \times 42{\cdot}347$ becomes $\frac{24{\cdot}7}{42{\cdot}7} \times 42{\cdot}347$

And

(24·7 on A − 42·7 on N or B) + 42·347 on N or B, gives 24·4 tons on A for the breaking weight of pillar in example.

And, as in Hodgkinson's "Experimental Researches," faced cast iron pillars, similar to last example, are demonstrated to be three times the strength of similar dimensions with ends rounded; and pillars with rounded ends correspond most nearly with practice; then, assuming constant = 42 ÷ 3 = 14 tons ultimate strength of pillars of cast iron, inch diameter, 1 ft. long; and $\frac{1}{5}$ for safe load.

14 ÷ 5 gives 2·8 constant, by which the next example is calculated.

Ex.—Required the safe load for cast iron pillar, 20 feet long, external diameter being 8 ins., internal diameter 6 ins., and the calculation from constant 2·8.

In 1st place—The formula for hollow cast iron pillars applied to this example becomes

$$\frac{8^{3\cdot5}-6^{3\cdot5}}{20^{1\cdot63}} \times 2\cdot8 = \text{safe load in tons.}$$

And as

Log. of 8 = 0·903
- of 6 = 0·778
- of 20 = 1·301

Log. 0·903 × 3·5 = Log. 3·16
- 0·778 × 3·5 = - 2·723
- 1·301 × 1·63 = - 2·12

Log. 3·16 = 1446 = $8^{3\cdot5}$
- 2·723 = 528 = $6^{3\cdot5}$
- 2·12 = 132 = $20^{1\cdot63}$

The question becomes $\frac{1446-528}{132} \times 2\cdot8 = \frac{918}{132} \times 2\cdot8$

And

(918 on A − 132 on N or B) + 2·8 on N or B = Ans. 19·5 tons safe load, on A.

Or, for questions of figures involving powers expressed by any Index, the line Common Logarithms and contiguous line Numbers, can be applied in similar manner to that shown by the 3·5 and 1·63 powers in above example, and pages 39 and 40.

PULLEYS AND WHEELS.

In making calculations of relative diameters and speeds of above, it is convenient to assume the "Driver" pulley, or wheel, as that, which has both its diameter and speed given, and the "Driven" that, for which one of those terms is required; and this being done,

Then, by Slide Rule,

The given term of "Driven" on A
Set to similar do. - "Driver" on N or B
Opp. remaining do. - do. - on A
Is required do. of "Driven" on N or B

Ex. 1.—A leather belt or strap connects a Pulley 36 inches diameter with one 28 inches; required the speed of latter when former makes 84 revolutions per minute.

Here "Driven" pulley (28 ins.) on A
Set to "Driver" pulley (36 ins.) on N or B
Opp. - do. - speed (84 revs.) on A
Is - "Driven" - do. (108 revs.) on N or B.

Ex. 2.—A line shaft and pulley making 136 revolutions per minute, are connected by strap with pulley 17 ins. diam. making 280 revolutions in same time; required the diameter of pulley on line shaft.

Here, speed of "Driven" (136 revs.) on A
Set to do. of "Driver" (280 revs.) on N or B
Opp. diam. of - do. - (17 ins.) on A
Is - do. - of "Driven" (35 ins.) on N or B = Ans.

Or, by inverting the slide N or $\frac{B}{C}$

Diameter of "Driver" (17 ins.) on N or $\frac{D}{d}$
Set to speed of - do. - (280 revs.) on A
Opp. to do. of "Driven" (136 revs.) on N or $\frac{D}{d}$
Is diameter of - do. - (35 ins.) on A = Ans.

Ex. 3rd.—Suppose a train of shafts and wheels:

On 1st shaft, Wheel 36 Cogs driving 27 on 2nd shaft,
2nd do. - do. - 30 do. - do. - 24 on 3rd do.
3rd do. - do. - 28 do. - do. - 21 on 4th do.

Required the speed of each shaft, when first makes 92 revolutions per minute.

Using the slides N and $\frac{B}{C}$ alternately, without inverting.

1st— 27 cogs on A set to 36 cogs on N
Opp. 92 revs. on A is nrly. 122·5 revs. on N for 2nd shaft

2nd— 24 cogs on A set to 30 cogs on B
Opp. 122·5 revs. on A is nrly. 153 revs. on B for 3rd shaft

3rd— 21 cogs on A set to 28 cogs on N
Opp. 153 revs. on A is nrly. 204 revs. on N for last shaft

Or, using the slides inverted, alternately,

1st— 36 cogs on $\frac{N}{}$ set to 1st speed 92 revs. on A,
Opp. 27 do. - $\frac{N}{}$ is 2nd do. 122·5 do. - A,

2nd—30 do. - $\frac{O}{d}$ set to 2nd do. 122·5 do. - A,
Opp. 24 do. - do. is 3rd do. 153 do. - A,

3rd—28 do. - $\frac{N}{}$ set to 3rd do. 153 do. - A,
Opp. 21 do. - $\frac{N}{}$ is 4th do. 204 do. - A,

The advantage of using even one slide inverted being shown as follows:—

Ex. 4.—Suppose for readjusting mill machinery, three 36 inch pulleys on line shaft make 128 revs. per minute.

1st to drive machine pulley 230 revs.
2nd - - do. - - do. - 280 do. and
3rd - - do. - - do. - 290 do. in same time.

Required the respective diameters of machine pulleys.

Here, 128 revs. on $\frac{N}{}$ or $\frac{O}{d}$ set to 36 in. pulley on A
Opp. 230 do. - do. is nrly. 20 in. do. - do.
- 280 do. - do. - do. 16·5 in. do, - do.
and 290 do. - do. - do. 15·9 in. do. - do.,

from one setting of $\frac{N}{}$ or $\frac{O}{d}$.

Ex. 5.—Required the diameter of spur wheel containing 86 cogs, $3\frac{1}{4}$ inches pitch.

The circumference of any circle being in proportion to its diameter very nearly 22 to 7,

As 22 : 7 :: any No. of cogs : diam. of wheel, inch pitch,

And

Last result × any pitch = diameter for that pitch.

Or, By Slide Rule,

As wheel with 22 cogs, inch pitch = 7 ins. diam.

1 (in.) on N set to 7 ins. - - on A
Opp. $3\frac{1}{4}$ - - on do. is 22·75 ins. - on A

And

22 (cogs) on B set to 22·75 ins. - on A
Opp. 86 do. on B is nrly. 89 in. diam. on A = Ans.

Or, with slides N, B, thus set,

For 22 cogs,
Any diam. is on A opposite the pitch on N; and
For 3·25 inches pitch,
Any number of cogs is on B. opposite the diameter on A.

Ex. 6.—Required the pitch of wheel 48 inches diameter containing 76 cogs.

Here, 7 on N set to 22 (cogs) on A
Opp. 48 on N is 151 do. on A, inch pitch.

And, as there are 76 cogs in example, 151 ÷ 76,

Or,

151 on A − 76 on N or B = 1·99 ins. pitch on A = Ans.

Or, 76 on N or B set to 151 inches - on A
Opp. 1 on - do. - is Ans. 1·99 do. on A as before.

Ex. 7.—For spur wheel 53 inches diameter, required the number of cogs 1·5 inches pitch.

Here, 7 (ins. diam.) on N set to 22 (circum.) - - on A,
Opp. 53 - do. - on do. is 166·5 cogs, inch pitch, on A,
And, as the pitch required is 1·5 ins.,

166·5 on A − 1·5 on B = 111 cogs on A

Or,

(22 on A − 7 on N) + 53 on N − 1·5 on B = Answer 111 Cogs on A as before.

Again.—To find the diameters of wheels for properly gearing two shafts whose speeds and distance between centres are given.

Arithmetically,

As Sum of Speeds - - : Twice distance between centres
:: Speed of either Wheel : Diam. of Wheel it works in.

Or, By Slide Rule,

Speed of Driver on N
Do. Driven on B } set to sum of their speeds on A

Opp. { Twice the distance between centres on A } is { Diam. of Driven on N / Do. Driver on B }

Ex. 1st.—A driving Shaft makes - 70 revs. per minute
The driven do. - do. - 80 do. - do.
- distance between centres = 85 inches;
required the diameter of wheels.

Here, sum of speeds - - - = 70 + 80 = 150
twice distance of centres = 85 × 2 = 170

And, { Driver 70 on N, / Driven 80 on B, } set to 150 - - - on A

Opp. 170 on A are { Driven wheel 79·3 ins. diam. on N / Driver do. 90·7 do. - on B } = Ans.

LEATHER BELTS OR STRAPS.

The capabilities of leather belts, for transmitting power by means of pulleys, are variously estimated by different authorities.

1st.—Fairbairn, in his "Treatise on Mills and Millwork" gives 3·6 inches approximate width for transmitting 1 Horse Power over pulley 1 ft. diameter; 9 inches approximate width for transmitting 10 Horses Power over pulley 4 ft. diameter, velocity of 1500 and 1800 feet per minute.
And "With greater velocities the breadth may be proportionably decreased."

Now, assuming the above belts capable of transmitting the stated powers by adhesion to half the periphery of the respective pulleys, when velocity 1500 feet per minute.

1 ft. diam. = 3·1416 = 1·5708 ft. for ½ periphery
4 ft. do. = 12·5664 = 6·2832 do. - - do.

1 Horse Power = 33000 lbs. lifted 1 ft. per minute.
10 Horses Power = 330000 - do. - 1 ft. do.

33000 ÷ 1500 = 22 lbs. tension, on 3·6 ins. strap
330000 ÷ 1500 = 220 - do. - on 9 ins. do.

22 ÷ 3·6 = 6·1 lbs. per inch wide.
220 ÷ 9 = 24·44 - do. - do.

6·1 ÷ 1·5708; or 24·4 ÷ 6·2832 or 3·88 lbs. represents the adhesion per lineal foot of belt inch wide, which if applied to

Pulley 1 ft. diameter = 6·1 lbs. on ½ periphery
Do. 2 ft. do. = 12·2 lbs. do. - do.
Do. 3 ft. do. = 18·3 lbs. do. - do.
Do. 4 ft. do. = 24·4 lbs. do. - do.

and so on.

2nd.—The "Engineer" of 1860 gives an extract from the "Scientific American," wherein a belt inch wide, having velocity 1000 feet per minute, is represented capable of transmitting ·927 horses power.

·927 Horses Power = 30591 lbs. lifted one ft. per minute.
30591 ÷ 1000 = 30·591 lbs. tension on belt.

and

30·591 lbs. adhesion applied to half the periphery of 2 ft. pulley gives

30·591 ÷ 3·1416 = 9·73 lbs. adhesion per lin. ft.

3rd.—The "Practical Treatise on Mill Gearing," by Thomas Box, the talented author of "Practical Hydraulics," "Treatise on Heat," &c., says a single leather strap 6 inches wide "drove well 3 Horses Power from pulley 2 ft. diam. making 90 revolutions per minute; but failed with 1 ft. 3 in. pulley running same speed," the arc of pulley embraced by strap in both cases being very nearly one half the periphery.

Working from the data afforded by 2 ft. pulley, 90 revolutions per minute, leather strap 6 inches wide, 3 Horses Power.

1st.—Velocity of Strap = 2 × 3·1416 × 90 = 565·488 ft. per. min.
2nd.—3 Horses Power = 33000 × 3 = 99000 lbs. lifted 1 ft. do.
3rd.—99000 ÷ 565·488 = 175 lbs. tension on 6 inch strap.
4th.— 175 ÷ 6 = 29·166 lbs. tension on inch strap.

And

5th.—As half the circumference of 2 ft. pulley, is 3·1416 feet.
29·166 ÷ 3·1416 = 9·3 lbs. adhesion per lineal foot.

Or, by Reduction,

A single leather strap inch wide, embracing half the circumference of 2 ft. pulley making 180 revolutions per minute, is capable of transmitting one Horse Power.

By Slide Rule,

1st.—2 (ft. Pulley) on N set to 1 (Horse Power) on A
Opp. Any diam. - on N is corresponding power on A
for 180 revolutions per minute, strap inch wide.

2nd.—180 (revs.) on B set to last result - - on A
Opp. any No. of revs. on B is corresponding power on A
for inch strap. And,

3rd.—1 (in. strap) - - on N set to last result on A
Opp. Any width of strap on N is the power - on A
for the new dimensions and speed.

Ex. 1st.—Required the horses power that can be effectually transmitted by single leather 6 inches strap embracing half the circumference of pulley 3 ft. diameter making 192 revolutions per minute.

1st.—2 (ft. diam.) on N set to 1 (Horse Power) on A
Opp. 3 (ft. diam.) on N is 1·5 - do. - on A
for 3 feet pulley, 180 revolutions per minute.

2nd.—180 (revs.) on B set to 1·5 (Horse Power) on A
Opp. 192 (revs.) on B is 1·6 - do. - on A
for 3 ft. pulley, making 192 revs. per minute.

And

3rd.—1 (in. strap) on N set to 1·6 (Horse Power) on A
Opp. 6 (in. strap) on N is 9·6 - do. - on A
for Answer.

Or, When the power and one of the other terms are given to find the remaining term, answers are obtainable in similar manner.

POWER OF COG WHEELS.

To find the number of Horses Power the cogs, or teeth of wheels are capable of transmitting; Benjamin Hick, founder of the celebrated engineering firm, Messrs. Benj. Hick & Son, Bolton, adopted in his extensive practice the

RULE.—"Multiply the square of the pitch in inches by the breadth of the teeth in inches, and the product will give the Horses Power when the velocity of pitch line is 16 feet per second," and in proportion for other speeds.

And as 16 ft. per second - - = 960 ft. per minute,
and
100 revs. per min. of 1 ft. wheel = 314·16 ft. - do. -

By Mr. Hick's Rule.—Spur Wheels 1 ft. diameter, inch pitch, two pitches broad, making 100 revolutions per minute, are capable of transmitting.

$$\frac{1^2 \times 2 \times 314{\cdot}16}{960} = {\cdot}6545 \text{ Horse Power.}$$

And Spur Wheels 1 ft. diam. on pitch line representing very nearly 37·7 inches circumference.

= 37·7 Cogs, 1 inch pitch
= 18·8496 do. 2 ins. do.
= 12·5664 do. 3 do. do.
= 9·4248 do. 4 do. do.;

the number of cogs in any wheel of given diameter being inversely to its pitch, and the power of Spur Wheels of similar diameters, two pitches broad, being directly proportionate to their respective pitches cubed, as shown next page.

Spur Wheels, 1 Ft. Diam.

Pitch.	Breadth.	No. of Cogs.	Horses Power at 100 revs. per minute.
1 inch...	2 ins.	37·6992	·6545
1⅛ ...	2¼ ...	33·5104	·932
1¼ ...	2½ ...	30·1592	1·278
1⅜ ...	2¾ ...	27·4176	1·702
1½ ...	3 ...	25·1328	2·209
1⅝ ...	3¼ ...	23·20	2·808
1¾ ...	3½ ...	21·5424	3·508
1⅞ ...	3¾ ...	20·106	4·315
2 ins. ...	4 ...	18·8496	5·237
2⅛ ...	4¼ ...	17·7408	6·281
2¼ ...	4½ ...	16·7552	7·456
2⅜ ...	4¾ ...	15·8732	8·769
2½ ...	5 ...	15·0796	10·228
2⅝ ...	5¼ ...	14·3616	11·839
2¾ ...	5½ ...	13·7088	13·613
2⅞ ...	5¾ ...	13·1126	15·565
3 ins. ...	6 ...	12·5664	17·673
3⅛ ...	6¼ ...	12·0637	19·976
3¼ ...	6½ ...	11·6	22·46
3⅜ ...	6¾ ...	11·17	25·16
3½ ...	7 ...	10·7712	28·06
3⅝ ...	7¼ ...	10·4	31·18
3¾ ...	7½ ...	10·053	34·52
3⅞ ...	7¾ ...	9·7288	38·08
4 ins. ...	8 ...	9·4248	41·89
4¼ ...	8½ ...	8·8704	50·25
4½ ...	9 ...	8·3776	59·65
4¾ ...	9½ ...	7·9366	70·15
5 ins. ...	10 ...	7·5398	81·82
5¼ ...	10½ ...	7·1808	94·71
5½ ...	11 ...	6·8544	108·9
5¾ ...	11½ ...	6·5563	124·4
6 ins. ...	12 ...	6·2832	141·4

APPLICATION OF TABLE AND SLIDE RULE.

Ex. 1st.—Required the Power of Spur Wheel, 6 ft. 3 in. diameter, $3\frac{1}{4}$ inches pitch, making 100 revolutions per minute, when breadth of cogs = twice the pitch, same as Table.

According to Table, wheel 1 ft. diameter, $3\frac{1}{4}$ ins. pitch, $6\frac{1}{2}$ ins. broad, making 100 revolutions per minute being equal 22·46 Horses Power.

1 (ft. diam.) on N or B, set to 22·46 (H.P.) on A
Opp. 6·25 do. - - do. - is 140·5 do. on A = Ans.

Ex. 2nd.—Required the Power of Spur Wheel 5 ft. 9 in. diameter, making 83 revolutions per minute, when pitch $2\frac{3}{4}$ ins. and breadth 8 inches.

From Table.—A wheel 1 ft. diam., $2\frac{3}{4}$ ins. pitch, $5\frac{1}{2}$ ins. broad, making 100 revolutions per minute, being equal to 13·613 Horses Power.

1 (ft. diam.) on line N set to 13·6 (Horses Power) on A
Opp. 5·75 diam. - on - do. is 78·2 - do. nrly. on A
for power of wheel 5 ft. 9 ins. diam., $2\frac{3}{4}$ ins. pitch, $5\frac{1}{2}$ ins. broad, making 100 revs. per minute. And, as the wheel is 8 ins. broad, and makes only 83 revs. per minute—

1st.—5·5 (ins. broad) on N set to 78·2 Horses Power on A
Opp. 8 ins. broad - on N is 113·5 - do. - on A

2nd.—100 (revs.) on B set to 113·5 Horses Power on A
Opp. 83 revs. on B is 94·5 do. nrly. on A=Ans.

Or, with slide B thus set, the figures and divisions on A represent the powers corresponding to any number of revolutions shown by the opposite figures and divisions on B, for same dimensions of wheel

142 H.P. on A being opp. 125 revs. on B
159 - do. - - do. - 140 - do.
170 - do. - - do. - 150 - do.

and so on.

Ex. 3rd.—Required the Pitch of Spur Wheel to drive 118 Horses Power, the diameter being 6 feet, the breadth equal twice the pitch, and the speed 100 revolutions per minute.

So far as this example is concerned, the speed, and proportion of breadth to pitch are the same as Table is calculated for. And 118 Horses Power for 6 ft. diam., or $118 \div 6 =$ 19·66 Horses Power per foot, which corresponds very nearly to $3\frac{1}{8}$ pitch.

Ex. 4th.—Required the diameter of Spur Wheel for transmitting 126 Horses Power when making 112 revolutions per minute; the pitch being $3\frac{1}{4}$ inches, and breadth equal twice the pitch, or $6\frac{1}{2}$ inches.

The speed in this example being 112 revolutions per minute, and the Table calculated for 100; to reduce the terms of example to suit the Table.

As 112 revs. : 126 Horses Power :: 100 : 112·5

Or (126 on A—112 on N, or B) + 100 on N, or B, = 112·5 horses power on A, for speed 100 revolutions per minute.

And, as, according to Table, spur wheel 1 ft., or 12 ins. diameter, is capable of transmitting 22·46 Horses Power—

Arithmetically,

$$\frac{112{\cdot}5 \times 12}{22{\cdot}46} = 60 \text{ inches diameter.}$$

Or,

$$112{\cdot}5 \div 22{\cdot}46 = 5 \text{ ft. - - do.}$$

By Slide Rule,

(112·5 on A − 22·46 on N or B) + 12 on N or B

Or, 22·46 on N or B set to 112·5 on A
Opp. 12 on do. is Ans. 60 inches on A

Or, 112·5 on A − 22·46 on N or B

Or, 22·46 on N or B set to 112·5 on A
Opp. 1 on do. is Ans. 5 ft. on A as before.

And, By finding the average diameter and pitch, the approximate strength or power of

MITRE OR BEVEL WHEELS

can be obtained in similar manner to spur wheels.

Ex. 1st.—Required the approximate power of bevel wheels whose breadth=7 inches, pitch=$3\frac{1}{4}$ ins., the largest wheel being 5 ft. diameter, making 112 revolutions per minute, containing 58 cogs, and working into wheel whose diameter is 3 ft. $9\frac{1}{2}$ ins.

Here, Radius of largest wheel $= 60 \div 2 = 30$ inches,
Do. smallest do. $= 45{\cdot}5 \div 2 = 22{\cdot}75$ ins.;
30 and 22·75 represent two sides of a right-angle triangle whose hypothenuse is equal

$$\sqrt{(30^2 + 22{\cdot}75^2)}.$$ And

As 30 on D is opposite its square - 900 on A
and 22·75 on D - do. - - do. nrly. 518 on A,

and their sum 1418 on A is opposite its square root very nearly 37·6 on D. So, 37·6 inches represents very nearly the hypothenuse of triangle formed by lines showing the junction of wheels; 37·6 ins., less half breadth of wheel, or 3·5 ins. = 34·1 inches average hypothenuse.

As 37·6 : 30 :: 34·1 : 27·2 ins. av. rad. of large wheel
27·2 × 2 - - = 54·4 ins. av. diam. of do,
54·4 ins. diam. = 171 ins. circumference for 58 cogs.

171 on A − 58 on N or B = 2·95 on A, or rather more than $2\frac{7}{8}$ ins. pitch.

And, as according to the Table, a spur wheel 12 ins. diam., $2\frac{7}{8}$ ins. pitch, making 100 revs. per min. = 15·565 H.P.
Constant 12 (ins.) diam. on N set to 15·565 H.P. on A
Opposite 54·4 ins. do. on N is nrly. 71 H.P. on A for 100 revs.

100 (revs.) on B set to 71 H.P. - - on A
Opp. 112 do. on B is 79·5 H.P. nrly. on A
for wheel $6\frac{1}{2}$ ins. broad, 112 revolutions per minute.

And 6·5 (ins.) on N set to 79·5 H.P. on A
Opp. 7 ins. on N is nrly. 85·6 H.P. on A = Ans.

THE STRENGTH OF SHAFTS TO RESIST TORSION.

Fairbairn, in his Treatise on "Mills and Millwork" says, Buchanan's Rules for power transmitted by shafts whose diameters are given in inches, are

"For Fly Wheel Shafts

$$\text{Diam.} = \sqrt[3]{\text{H.P.} \div \text{Revs. per min.} \times 400} \quad \text{(1)}$$

"For Water Wheel Gearing and other heavy work

$$\text{Diam.} = \sqrt[3]{\text{H.P.} \div \text{Revs. per min.} \times 200} \quad \text{(2)}$$

"For ordinary Mill Gearing

$$\text{Diam.} = \sqrt[3]{\text{H.P.} \div \text{Revs. per min.} \times 100} \quad \text{(3)}$$

"An ordinary allowance for Wrot. Iron Shafting

$$\text{Diam.} = \sqrt[3]{\text{H.P.} \div \text{Revs. per min.} \times 250} \quad \text{(4)}$$

Or, $\dfrac{\text{Diam. cubed} \times \text{Revs. per min.}}{\text{Constant}} = \text{H.P., or Horses Power}$

And

Taking the force in Foot Pounds, for Dividends; and Revs. per min. × by following constants, for Divisors; the quotients of former by latter, give same results as derived from preceding formula.

The results from

Constant 82·5 being like those from (1)
Do. 165 - do. - - do. - (2)
Do. 330 - do. - - do. - (3)
Do. 132 - do. - - do. - (4)

A shaft capable of transmitting four horses power when making 100 revolutions per minute, reckoning by constant 82·5, being obtained thus:

4 Horses Power = 33000 × 4 = 132000 Foot Pounds

And $\dfrac{132000}{100 \times 82{\cdot}5}$ = diam. of shaft cubed, corresponding to formula (1).

Strength of shafts 4 inches diameter, calculated for 100 revolutions per minute, and various Divisors.

Divisors	100	150	200	250	400
Horses Power... ...	64	42·66	32	25·6	16

To find by improved Slide Rule, the Power, or Diameter, or revolutions of shaft per minute; when the divisor and other terms are given;

1st.—To find the Power when diameter, revolutions per minute, and any divisor in Table are given.

Const. 4 (ins. diam.) on Cu. Rt. line, set to H.P. on N
Opp. any ins. diam. on - do. - is - do. on N
for 100 revolutions per minute. And

Const. 100 - - - - - on B, set to last result on A
Opp. any number of revs. on B, is Answer - - on A

Ex.—Required the power of 6 inch round shaft making 110 revolutions per minute, calculated by Divisor 250.

From Table, under given divisor 250, 4 ins. round shaft making 100 revolutions per minute being = 25·6 H.P.
4 (ins. diam.) on Cu. Rt. line, set to 25·6 (H.P.) on N
Opp. 6 (ins. diam.) - do. - is - 86·4 do. - N,
for same number of revolutions. And
100 (revs.) on B set to 86·4 (Horses Power) on A
Opp. 110 (revs.) on B is - 95 Horses Power on A=Answer.

2ndly.—To find the diameter of shaft when power, number of revolutions per minute, and any divisor in Table, are given.

The given revs. on B set to given power on A,
Opp. 100 (revs.) on B is horses power on A for given shaft making 100 revs. per minute.

And as the Table is calculated for 4 in. shaft, 100 revs. per minute,

H.P. for divisor set on N to 4 (ins. diam.) on Cu. Rt. line
Opp. H.P. of shaft at 100 revs. per min. on N. will be the required diam. on Cu. Rt. line.

Ex.—A round shaft making 110 revolutions per minute, is required to transmit 95 horses power calculated from divisor 250; what must be the diameter of shaft?

Here, 110 (revs.) on B set to 95 (horses power) on A
Opp. 100 do. on B is 86·4 - do. - on A
for 100 revolutions per minute.

And as (according to Table) 4 ins. shaft, 100 revolutions per minute, divisor 250, = 25·6 horses power.

25·6 (H.P.) on N set to 4 (diam.) on Cu. Rt. line
Opp. 86·4 do. on N is 6 ins. diam. - do. - for Ans.

3rd.—To find the revolutions of shaft per minute, when diameter, power, and divisor are given.

Having taken the power of 4 inch shaft, corresponding to divisor in Table,

4 (ins. diam.) on Cu. Rt. line set to H. P. on N
Opp. any do. - - do. - - is its do. on N
for 100 revolutions per minute. And,

Last result on B set to 100 revs. on A
Opp. any power on B = Answer on A.

Ex.—A round shaft 6 inches diameter, is required to transmit 95 horses power calculated from divisor 250; what is the speed of shaft?

From Table, under Divisor 250, is 25·6 horses power for 4 inch shaft making 100 revolutions per minute.

4 (diam.) on Cu. Rt. line set to 25·6 (H.P.) on N,
Opp. 6 do. - - do. - - is 86·4 (H.P.) on N for same speed; and as the required power is 95 horses,

86·4 (H.P.) on B set to 100 revolutions on A
Opp. 95 (H.P.) on B is 110 - do. - on A = Ans.

Ex.—Required the diameters of various shafts belonging to a double geared crane, calculated by the Formula derived from Buchanan's constant 100

$$= \frac{\text{Foot pounds per minute}}{\text{Revs. per minute} \times 330} = \text{Diameter},$$

The Maximum force applied to winch - - being 110 pounds,
Circumference of winch circle - - - = 8 ft.
Revolutions of winch shaft per minute = 20, and
Proportion of each of two pinions to wheel it works in - - - - - } 1 to 5

In 1st place, Arithmetically,
110 pds. × 8 ft. × 20 revs. = 17600 ft. pds. per min.
2ndly.—As proportion of each pinion to wheel is 1 to 5,
Winch shaft making 20 revs. per minute,
2nd Motion Shaft = 4 do. - do.
Barrel Shaft - - = ·8 do. - do.

3rdly.— $\sqrt[3]{\frac{17600}{1 \times 330}} = \sqrt[3]{53{\cdot}3}$ = nrly. 3·77 ins. diam. for 1

$\sqrt[3]{\frac{53{\cdot}3}{20}} = \sqrt[3]{2{\cdot}67} =$ 1·39 - do. - for 20

$\sqrt[3]{\frac{53{\cdot}3}{4}} = \sqrt[3]{13{\cdot}3} =$ 2·37 - do. - for 4

$\sqrt[3]{\frac{53{\cdot}3}{{\cdot}8}} = \sqrt[3]{66{\cdot}7} =$ 4·06 - do. - for ·8

revolutions per minute. Or, By Slide Rule,

8 on A+ 20 on N = 160 ft. speed of winch on A
160 on A+110 on B = 17600 ft. lbs. per min. on A
17600 on A−330 on N = 53·3 on A=diam.^{3} for 1 rev.
53·3 on A− 20 on B = 2·67 on A= do. for 20 revs.
53·3 on A− 4 on N = 13·3 on A= do. for 4 revs.
53·3 on A− ·8 on B = 66·7 on A= do. for ·8 rev. per minute.

The diameters of respective shafts being on
Cube Root line nrly. 1·39; 2·37; 4·06 Inches;
Opposite - 2·67; 13·3 ; 66·7 do. on line N.

STEAM ENGINES.

In applying the improved Slide Rule to calculations relating to work done by steam engines, computers will do well to notice that 14 indicated horses power is transmitted when

Steam Cylinder - - - 14 inches diameter.
Velocity of Piston - - 300 ft. per minute.
Av. eff. pressure on do. - 10 lbs. per sq. inch.

And

The Power of any other steam engine in proportion to the above, being directly as the respective areas of cylinders, speeds of pistons, and effective pressures.

By Slide Rule,

1st.—Diameter 14 (ins.) on D, set to 14 (H.P.) on C,
Opp. any Diam. do. - D, is - - (H.P.) on C,
for piston speed 300 feet per minute, and effective pressure 10 pounds per square inch.

2nd.—Constant 300 (ft.) - on N, set to last result on A
Opp. any speed in ft. on N, is horses power on A

3rd.—Const. 10 (lbs. per sq. in.) on B, set to last result on A
Opp. any - do. - , is Answer - - - on A

Ex. 1st.—Required the indicated horses power of Steam Engine, Cylinder being 31 ins. diam., Piston speed 350 feet per minute, av. effective pressure throughout stroke 18 pounds per square inch.

1st.— 14 (in. cy.) on D set to 14 horses power - on C
Opp. 31 (do.) on D is 68·6 - do. - - on C

2nd.—300 (ft.) - on N set to 68·6 - do. - - on A
Opp. 350 (ft.) - on N is 80 - do. - - on A

3rd.— 10 (pds.) - on B set to 80 - do. - - on A
Opp. 18 (pds.) - on B is 144 - do. = Ans. on A

Ex. 2nd.—Required the indicated power of Steam Engine when cylinder 40 ins. diameter, speed of Piston 396 feet per minute, and effective average pressure on piston throughout stroke = 19·5 pounds per square inch.

Here,

1stly.—14 (ins. cyl.) on D set to 14 (Horses Power) on C
Opp. 40 do. on D is 114 - do. - on C, for speed 300 feet per minute, and pressure 10 pounds per sq. in.

2ndly.—300 (feet) on N set to 114 Horses Power on A,
Opp. 396 (feet) on N is 150 - do. - on A, for speed 396 feet per minute, 10 pounds pressure. And

3rdly.—10 (pounds) on B set to 150 Horses Power on A
Opp. 19·5 do. on B is 292 - do. - on A=Ans.

Ex. 3rd.—Suppose a steam engine has to indicate 270 Horses Power when speed of Piston = 450 feet per minute, and the average effective pressure throughout stroke = 18·5 pounds per square inch. Required the diameter of cylinder.

The speed of Piston in this example being 450 feet per minute, and the pressure 18·5 pounds per square inch; it is obvious that less diameter of cylinder will be required to drive 270 Horses Power than would be for speed 300 feet and pressure 10 pounds; and as the data "14 ins. cylinder = 14 Horses Power" is for the latter speed and pressure, so, to use the data, the terms in example must be reduced accordingly.

1stly.—450 (Feet) - on N set to 270 (Horses Power) on A
Opp. 300 do. - on N is 180 (do.) on A

2ndly.— 18·5 (Pounds) on B set to 180 (do.) on A
Opp. 10 (do.) on B is 97·3 (do.) on A

And, the example being thus reduced

3rdly.—14 (Horses Power) on C set to 14 (ins. cylin.) on D
Opp. 97·3 Horses Power on C is nrly. 37 inches - on D for the required diameter of cylinder.

Ex. 4th.—Suppose two equal-sized common lift pumps have to discharge 600 gallons of water per minute to a height of 90 feet. Required the diameter of pumps, and the indicated Horses Power of steam engine for working them, reckoning

10 per cent. of the nett quantity for leakage,
50 - do. - - - gross do. - for friction,

and the bucket of each pump to make 10 lifts of 5 ft. stroke per minute.

In 1st place.—The nett quantity = 600 gallons per minute,
plus 10 per cent. for leakage = 60 do. - - do.
makes the total quantity = 660 do. for 2 pumps.

2ndly.—660 ÷ 2 = 330 gallons per minute for each pump,
330 ÷ 10 = 33 do. for stroke of - do. -
33 ÷ 5 = 6·6 do. per foot of stroke of do. -

Or,

By Slide Rule,

660 on A — 2 on N or B = 330 galls. on A for each pump
330 on A — 10 on do. = 33 do. on A per stroke of do.
33 on A — 5 on do. = 6·6 do. on A per ft. of stroke.

And, as according to Table (page 97) the contents of cylinder 12 inches diameter, 1 foot long = 4·897 (say 4·9) gallons,

1st.—4·9 (galls.) on C set to 12 (ins. diam.) on D
Opp. 6·6 do. on C is 13·92 (ins. diam.) on D for each pump.

And, as from page 63
3300 galls. of water lifted 1 ft. per min. = 1 Horse Power.

2nd.—3300 (galls.) on N set to 1 Horse Power on A
Opp. 660 do. do. is ·2 - do. - on A

3rd.—For 90 feet lift,
1 (ft.) on B set to ·2 H.P. on A
Opp. 90 (ft.) on B is 18 do. on A

And 4thly.—As to lift 660 galls. per min. 90 ft. = 18 H.P.
50 per cent for friction - - - = 9 do.
The indicated power of Engine - = 27 Horses
for Ans.

EXPANSIVE STEAM ENGINES.

To find the average pressure of steam per sq. inch throughout the stroke of Steam Engines worked expansively, when the initial pressure in cylinder (including the atmosphere), and the distance the piston has moved from the commencement of its stroke when the steam is just shut off, are given.

1st.—Divide the whole length of stroke by the distance the piston has moved when the steam is just shut off, and the quotient will give the number of times the steam is expanded.

2nd.—The hyperbolic logarithm of last result gives the sum of average pressures per square inch from the point of cut off to the end of stroke, when the initial pressure one pound.

3rd.—The sum of (1 + last result) divided by the number of times the steam is expanded, will give the average pressure per square inch throughout the stroke.

And 4th.—The last result multiplied by any initial pressure (including the atmosphere) will give the average corresponding to that pressure for the same cut off.

Ex. 1st.—Required the average pressure of steam on the piston of a steam engine throughout its stroke, supposing the initial pressure (including the atmosphere) = 30 lbs. per sq. inch, and the steam just shut off when 20 inches of 60 inches stroke has been completed.

1st.—60 ÷ 20; Or, by Slide Rule,

60 on A — 20 on N or B gives 3 on A for the number of times the steam is expanded.

Or, the expansion is from one to three volumes.

2ndly.—Referring to the lines of NUMBERS, and HYP. LOG^{s}., on No. 2 Face of improved Slide Rule; 3 on NUMBERS line is opposite its hyperbolic logarithm 1·098; therefore, from what has already been said, 1·098 represents the sum of average pressures per square inch on piston for the two parts of stroke after steam is just shut off, when initial pressure one pound.

3rdly.—Initial pressure for 1 part of stroke = 1
Sum of averages for 2 parts of stroke = 1·098
Sum of averages for 3 parts of stroke = 2·098
Average throughout stroke = 2·098 ÷ 3 = nrly. ·7 lbs. per sq. in.

And 4thly.—As the initial pressure per square inch in example is 30 pounds, ·7 × 30 gives 21 lbs. per sq. inch = Ans.

Ex. 2.—Required the average effective pressure per square inch on Steam Engine Piston which has moved 9 inches of its 60 inches stroke when the steam just shut off; the initial pressure (including atmosphere) being 60 pounds per sq. inch, and the resistance per sq. inch from imperfect condensation, &c., 3 pounds.

In 1st place.—60 ÷ 9 gives $6\frac{2}{3}$ or nearly 6·67 for the number of times the initial volume of steam is expanded per stroke.

2ndly.—6·67 on NUMBERS line is opp. 1·898 on HYP. LOG^{s}. line.

3rdly.—$\frac{1+1\cdot898}{6.67}$ Or 2·898 on A — 6·67 on N gives nrly. ·434 pounds average pressure per sq. inch throughout stroke, when initial pressure 1 pound; or ·434 × 60 = 26 pounds when initial pressure 60 pounds. And

4thly.—Pressure propelling piston being = 26 lbs. per sq. in.
Resistance from imperfect condensation = 3 do. do.
Average effective pressure or answer = 23 do. do.

Ex. 3rd.—Required the initial pressure of steam in cylinder of steam engine worked expansively, the resistance from imperfect condensation, &c., being 4 pounds per square inch, effective average pressure 19 pounds, and the steam shut off when piston has moved one-fifth of its stroke.

1st.—The effective pressure being - 19 lbs. per sq. inch.
- do. resistance - - - 4 do. do.
- gross pressure on piston - 23 do. do.

2nd.—As the steam expands in cylinder from one to five volumes, and the hyp. log. of 5 is 1·609;

$\frac{1+1\cdot609}{5} = \frac{2\cdot609}{5}$ gives ·5218 lbs. gross average pressure per square inch on piston, reckoning the initial pressure per sq. inch one pound.

And 3rd.—23 ÷ ·5218; or 23 on A − ·5218 on N or B gives the initial pressure 44 lbs. per sq. inch on A = Ans.

Ex. 4th.—Required the proportion of stroke a steam engine piston has moved when steam just shut off, supposing

Initial pressure (including atmosphere) = 50 lbs. per sq. inch
Effective average throughout stroke - = 19 do. - do.
Resistance from imperfect condensation = 4 do. - do.

1st.—19 + 4 gives 23 lbs. per sq. inch for the gross average pressure on piston throughout its stroke.

2nd.—The initial pressure per square inch being 50 pounds 23 ÷ 50; or 23 on A − 50 on N or B gives ·46 pounds per sq. inch on A for gross average pressure when initial pressure 1 lb.;

And

3rd.—As from few trials it is seen that $\frac{1 + \text{Hyp. Log. of } 6\cdot1}{6\cdot1} = \frac{1 + 1\cdot81}{6\cdot1} = \frac{2\cdot81}{6\cdot1}$ = very nearly ·46, so $\frac{1}{6\cdot1}$ is the proportion of stroke required for Answer.

But the preceding calculations relating to steam engines worked expansively having been made without noticing the effect caused by contents of clearance and passage at each end of cylinder, and the contents (in many instances amounting to more than two inches of stroke) being greater in proportion for short strokes than long ones, the following rule and example are for finding the average pressure, when

Initial pressure per square inch - - = -	1 Pound
Whole stroke of piston in - - - - - - - -	Inches
Portion of stroke made when steam shut off -	do.
Do. - do. equal in content to clearance	do.

1st.—Piston stroke + clearance - call Increased Stroke,
Steam shut off + do. - call Increased Cut off.

2nd.—Divide the former by the latter and the quotient will give the ratio of expansion to 1.

3rd.—The hyperbolic logarithm of last result represents the sum of average pressures on piston per sq. inch after steam is shut off.

4th.—The last result divided by (ratio of expansion—1,) gives the average pressure on piston during its stroke after steam shut off.

5th.—Initial pressure (1 lb.) × Piston's motion before steam shut off, added to the product of average pressure × Piston's motion after steam shut off, the quotient of sum divided by the Piston's whole stroke will give the average throughout.

And 6th.—The last result multiplied by any other pressure of steam (always including the atmosphere) will give the average corresponding to that pressure.

Ex.—Required the effective average pressure per square inch on steam engine piston which has moved 9 inches of its 60 inches stroke when steam just shut off; the initial pressure per square inch being 60 pounds (including the atmosphere); the resistance per square inch from imperfect condensation, &c., 3 pounds; and the capacity of clearance and passage at each end of cylinder equal to 2 inches of stroke.

1st.—60 + 2 gives 62 inches for the increased stroke
9 + 2 do. 11 do. - - - do. cut off.

2nd.—62 on A—11 on N or B, gives 5·64 on A for the ratio of expansion to 1.

3rd.—Hyp. Log. of 5·64, or very nrly. 1·73, represents the sum of average pressures per square inch on piston during
5·64 − 1 = 4·64 parts of stroke,
assuming the initial pressure per sq. inch = 1 lb.

4th.—1·73 ÷ 4·64, or 1·73 on A − 4·64 on N or B gives nearly ·373 on A for the average pressure per square inch on piston, from when the steam is shut off to the end of stroke.

5th.—Initial pressure 1 lb. multiplied by the motion of piston before steam shut off } Or, 1× 9= 9lbs.
Average pressure ·373 multiplied by motion of piston after steam shut off } Or, ·373×51=19lbs.
Sum of averages for 60 inches stroke - - = - - 28lbs.

28 ÷ 60 gives nearly ·467 average per sq. in. throughout the stroke, for initial pressure one pound.

·467 × 60 gives 28 lbs. average for 60 lbs. initial pressure.

And 6th.—The av. pressure 28, less resistance 3, gives the effective average throughout stroke = 25 lbs. per sq. inch = Answer.

Or, compared with Ex. 2, page 136, this example shows only about 8 per cent. more power, whereas the consumption of steam is increased about 22 per cent.

And - - - - - - 0· - being Hyp. Log. of - 1
- 2·3025 × 1 = 2·3025 - do. - do. - - 10
- do. × 2 = 4·605 - do. - do. - - 100
- do. × 3 = 6·9075 - do. - do. - - 1000
&c. - - &c. - - - - &c. - - - &c.;

and the figures and divisions on Hyp. Logs. line representing hyperbolic logarithms of numbers only from 1 to 10 inclusive; it may here be observed that hyperbolic logarithms of numbers above 10, are obtainable from the same lines, by placing

1 (on Slide marked NUMBERS) to represent - - 10
Opp. the decimals ·3025 of hyp. log. of - - - - - - 10

1, or 10, on Slide to represent - - - - - - - - 100
Opp. the decimals ·605 of hyp. log. of - - - - - - 100

1, or 10, on Slide to represent - - - - - - - 1000
Opp. the decimals ·9075 of hyp. log. of - - - - - 1000

of any convenient radius on hyp. logs. lines, and (mentally) substituting proper whole numbers for the 0·, 1, 2, which only apply to numbers from 1 to 10.

EXAMPLES.

Required the Hyp. Logs. of 20, 40, 60.

Here, on Slide marked NUMBERS,
1 set for 10 to decimals ·3025 on 1st rad. Hyp. Logs. line,
2 = 20 is opp. do. ·996 - do. - do. - -
4 = 40 do. - do. ·69 - 2nd do. do. - -
6 = 60 do. - do. ·095 - 3rd do. do. - -

and with the proper whole numbers affixed, the
Answers = 2·996 nrly. for Hyp. Log. of 20
3·69 do. - - do. - - 40
4·095 do. - - do. - - 60, and so on.

Or,

Hyp. Logs. = Com. Logs. × 2·3 nrly., as shown Page 41.

COMMON SLIDE VALVES FOR STEAM ENGINES.

In considering the approximate positions of valves and pistons at various parts of engine stroke, it is here assumed that only one common slide valve is used; that the motion is given to the valves by ordinary eccentric, or crank; that the eccentric rod for valves, and connecting rod for engine crank are infinite length; and that of the steam and exhaust valves hereafter alluded to, the former is for admitting the steam to, and the latter for discharging the same from the cylinder.

To explain the technical terms "LAP and LEAD" of common slide valves for steam engines.

1st.—LAP represents the distance the steam valves cover the steam sides of ports, or openings, when the valves at half stroke.

2nd.—LEAD represents the distance one of the steam valves is open when engine crank pin on one of its dead centres.

3rd.—LAP + LEAD, represents the distance the valves have moved past their half stroke when engine crank pin on one of its dead centres.

4th.—LAP + LEAD + exhaust at its half stroke, represents the distance exhaust valve is open when engine crank pin on one of its dead centres.

5th.—Half stroke of valves − LAP, represents the distance the valves have returned from one end of their stroke, when steam port just closed.

6th.—The distance each exhaust valve is open at its half stroke, deducted from half stroke, represents the distance the valves have returned from one end of their motion when the exhaust port is just opening.

7th.—The distance the exhaust valve is open at its half stroke, added to its half stroke, represents the distance the valves have returned from one end of their motion when the exhaust port just closed.

And lastly.—For the approximate positions of Piston at the instants when steam just shut off, when exhaust port just opening, and exhaust port just closed.

The number of degrees from point corresponding with commencement of Piston stroke on circle described by centre of engine crank pin, is equal the number of degrees from point corresponding with "LEAD" on circle described by radius of valves' motion.

Ex.—The ports, or openings, of a steam cylinder are 3 ins. wide, the lap on steam valve is $2\frac{1}{4}$ inches, the lead $\frac{1}{8}$ inch, the exhaust valves open $\frac{1}{8}$ inch to both ends of cylinder when at their half stroke, the distance moved by the valves is 8 inches, and the radius of Engine Crank is 36 inches.—Required the following—

1st.—What is the steam valve past its half stroke when Engine Crank on one of its dead centres?

2nd.—What distance is the exhaust valve open when the Engine Crank on one of its dead centres?

3rd.—What distance have the valves returned from one end of their motion when the steam is just shut off from the cylinder?

4th.—What distance have the valves returned from one end of their motion when just opening the exhaust port?

5th.—What distance have the valves returned from one end of their motion when exhaust port just closed?

1stly.—The engine crank pin is on one of its dead centres, or the Piston is commencing a stroke, when the valves are past their centre of motion

$2\frac{1}{4}$ inches Lap + $\frac{1}{8}$ in. Lead = $2\frac{3}{8}$, or 2·375 inches.

2ndly.—The engine crank pin is on one of its dead centres when the exhaust valve is

$2\frac{1}{4}$ ins. Lap + $\frac{1}{8}$ in. Lead + $\frac{1}{2}$ in. exhaust opening at centre of valves' motion = $2\frac{7}{8}$, or, 2·875 inches.

3rdly.—The steam is just shut off from cylinder when the valves have returned from one end of their stroke = half stroke less Lap, or, $4 - 2\frac{1}{4} = 1\frac{3}{4}$, or 1·75 inches.

4thly.—The exhaust valve is just opening when the valves have returned their half stroke less what the exhaust is open to each end of cylinder at their half-stroke,

or, $4 - \frac{1}{2} = 3\frac{1}{2}$, or 3·5 inches.

5thly.—The exhaust valve has just closed when it has returned its half stroke plus what it is open to each end of cylinder at its half stroke,

Or, $4 + \frac{1}{2} = 4\frac{1}{2}$, or 4·5 inches,

And,

The radius of valve motion being $8 \div 2 = 4$ inches,
And for radius of - - do. - - 1 inch, the above results

$$= \begin{cases} 2{\cdot}375 \div 4 = {\cdot}594 & \text{inches nearly.} \\ 1{\cdot}75 \div 4 = {\cdot}4375 & \text{do.} \\ 3{\cdot}5 \div 4 = {\cdot}875 & \text{do.} \\ 4{\cdot}5 \div 4 = 1{\cdot}125 & \text{do.} \end{cases}$$

And, the engine crank pin being on one of its dead centres when the valves (with assumed radius of motion 1)

are ·594 past the middle of their stroke = sine nearly 36·5°
or, ·406 from one end of do. = versed sine nrly. 53·5°,
so the valves have just got to one end of their motion when

the engine crank pin has described nearly 53·5° of its circle. Or, taking

·406 = versed sine 53·5° = (Radius 1 − Cosine 53·5°)
·4375 = do. 55·8° = (do. 1 − do. 55·8°)
·875 = do. 82·8° = (do. 1 − do. 82·8°)
1·125 = 97·2° of a circle, = (do. 1 + Sine 7·2°)

The engine crank pin has moved from one of its dead centres.

53·5° when valves' motion in one direction just ended
53·5° + 55·8° = 109·3° when steam just shut off
53·5° + 82·8° = 136·3° when exhaust just opening
53·5° + 97·2° = 150·7° - do. - just closed

Or,

The versed sine of 53·5° for Radius 1 being = ·406
109·3° of a circle = Rad. 90° + Sine 19·3° do. = 1·33
136·3° - do. - = Rad. 90° + Sine 46·3° do. = 1·724
150·7° - do. - = Rad. 90° + Sine 60·7° do. = 1·872

Then, for Engine Crank 36 inches radius,

·406 × 36 = ·406 on A + 36 on N or B = 14·6 ins. on A
1·33 × 36 = 1·33 on A + do. - do. = 47·9 do. A
1·724 × 36 = 1·724 on A + do. - do. = 62· do. A
1·872 × 36 = 1·872 on A + do. - do. = 67·4 do. A

very nearly for Answers. That is,

1st.—The steam and exhaust valves will be $2\frac{3}{8}$ inches past their half-stroke when the engine crank pin is on one of its dead centres.

2ndly.—The exhaust valve will be open $2\frac{7}{8}$ ins. at that time.

3rdly.—The valves will have returned $1\frac{3}{4}$ ins. from one end of their stroke when the steam is just shut off, and the piston has moved 47·9 inches.

4thly.—The valves will have returned $3\frac{1}{2}$ inches from one end of their stroke when the exhaust just opening, and the piston has moved 62 ins.

Or 5thly.—The valves will have returned $4\frac{1}{2}$ ins. from one end of their stroke when the exhaust is just closed, and the piston has moved 67·4 inches.

And, in conclusion, the examples in this treatise affording only few towards innumerable instances where applications of Slide Rules are adapted for simplifying and facilitating calculations which by the usual modes of arithmetic are exceedingly tedious, the author earnestly subscribes to the remarks published in the celebrated Penny Cyclopædia of the Society for Diffusion of Useful Knowledge, and which literally apply at the present time:—

"The Sliding Rule has been greatly undervalued in our country in which it was invented, and is very little known on the Continent; for though a French work on the subject, published in 1825, assures us that in England the sliding rule is taught at schools at the same time with the letters of the alphabet, we feel safe in saying that nine Englishmen out of ten would not know what the instrument was for if they saw it, and that of those who even know what it is for, not one in a hundred would be able to work a simple question by means of it. For a few shillings most persons might put into their pockets some hundred times as much power of calculation as they have in their heads, and the use of the instrument is attainable without any knowledge of the properties of Logarithms, on which its principles depend."

although he believes a slight "knowledge of the properties of logarithms" essential, in rendering the application of Slide Rules to calculations easy and interesting.

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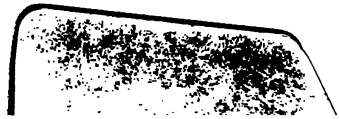
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